DRAFT ENVIRONMENTAL IMPACT STATEMENT
- DARWIN PORT EXPANSION -
EAST ARM

TABLE OF CONTENTS

SUMMARY

1. INTRODUCTION
   1.1 Objectives Of Proposal
   1.2 Scope Of EIS
   1.3 Preparation Of Draft EIS

2. NEED FOR PROPOSAL
   2.1 Existing Port Facilities
       2.1.1 Stokes Hill Wharf
       2.1.2 Fort Hill Wharf
       2.1.3 Iron Ore Wharf
       2.1.4 Roll-On Roll-Off Facility
       2.1.5 Ancillary Facilities
   2.2 Existing and Potential Demands for Port Facilities
   2.3 Ability of Existing Port to Meet Potential Demands
   2.4 Port Facilities Required to Meet Projected Demands

3. OPTIONS CONSIDERED
   3.1 The "No Action" Option
   3.2 Siting of New Port
   3.3 Earlier Investigations into East Arm Port
   3.4 Nature Of Proposed East Arm Port Facilities
       3.4.1 Proposed Port Configuration
   3.5 Staging of Development
       3.5.1 Stage 1
       3.5.2 Stage 2
       3.5.3 Stage 3
       3.5.4 Stage 4
       3.5.5 Alternative Development Programme

4. PROJECT DESCRIPTION
   4.1 Design of Port and Associated Facilities
       4.1.1 Berths
       4.1.2 Ship Support Facilities
       4.1.3 Urban Services Required
       4.1.4 Site Drainage and Wastewater Management
       4.1.5 Recreational and Educational Features

Page No.

1
20
21
22
25
27
27
29
29
30
31
33
35
35
4.2 Construction Process
4.2.1 Construction Methods
4.2.2 Dredging
4.2.3 Sources and Quantities of Fill
4.2.4 Extraction, Transport and Placement of Fill
4.2.5 Construction of Associated Transportation Infrastructure
4.2.6 Construction Schedule
4.2.7 Construction Workforce
4.2.8 Management of Construction Wastes

4.3 Revised Function of Port Facilities
4.3.1 Programme
4.3.2 Potential for Re-Use of Port Facilities
4.3.3 Future Uses of Land

4.4 Operation of Proposed Port
4.4.1 Shipping Movements
4.4.2 Types of Cargo
4.4.3 Loading and Unloading of Vessels
4.4.4 Cargo Storage and Handling
4.4.5 Land Transportation
4.4.6 Workforce
4.4.7 Maintenance Dredging
4.4.8 Waste Management
4.4.9 Contingency Plans for Emergencies

5. EXISTING CONDITIONS AND ENVIRONMENTAL EFFECTS

5.1 Terrestrial Environment
5.1.1 Existing Conditions
   Topography
   Geology and Soils
   Climate
   Flora
   Mammals and Reptiles
   Avifauna
5.1.2 Environmental Effects
   Construction Phase
   Operation
5.2 Estuarine Physico-chemical Environment
5.2.1 Existing Conditions
- Bathymetry
- Seabed Conditions
- Tides
- Storm Surge Levels
- Stratification
- Hydrodynamics of Darwin Harbour
- Water Quality

5.2.2 Environmental Effects
- Changes in Currents In Vicinity of Catalina Is.
- Modelling of Turbidity Levels during Construction
- Summary of Impacts on Physico-chemical Conditions

5.3 Estuarine Biological Environment
5.3.1 Existing Conditions
- Mangrove Communities
- Soft Seabed Biota
- Fish
- Plankton
- Hard Seabed Biota
- EIS Studies
- Shell Islands Habitat and Marine Biota
- Comparison Of Shell Islands With Other Locations
- Marine Mammals
- Marine Reptiles

5.3.2 Environmental Effects
- Construction Phase
- Operational Phase

5.4 Visual and Acoustic Environment
5.4.1 Existing Conditions
- Landscape Character
- Noise Levels

5.4.2 Environmental Effects
- Construction Phase
- Operational Phase

5.5 Historic and Archaeological Factors
5.5.1 Existing Conditions
- Archaeological Sites
- Sites of Significance to Aboriginal People
- Historic Features

5.5.2 Environmental Effects
- Construction Phase
- Operational Phase
5.6 Regional Planning and Socio-Economic Environment

5.6.1 Existing Conditions
- Regional Planning Strategy
- Existing Land Ownership
- Commercial Aquaculture Operations
- Indo Pacific Marine
- Recreational Use Of The Harbour

5.6.2 Environmental Effects
- Construction Phase
- Operational Phase

6. ENVIRONMENTAL SAFEGUARDS AND MONITORING

6.1 Environmental Safeguards

6.1.1 Construction Phase
- Terrestrial Environment
- Estuarine Environment
- Visual and Acoustic Environment
- Historic and Archaeological Factors

- Regional Planning and Socio-Economic Environment

6.1.2 Operational Phase
- Terrestrial Environment
- Estuarine Environment
- Visual and Acoustic Environment
- Historic and Archaeological Factors

- Regional Planning and Socio-Economic Environment

6.2 Monitoring

6.2.1 Construction Phase
6.2.2 Operational Phase

7. INFORMATION SOURCES, PUBLIC INVOLVEMENT AND CONSULTATION

7.1 Information Sources
7.2 Public Involvement And Consultation
Coral in Darwin Harbour

Existing Demands on Port Facilities
List of Coral Families Recorded
Results of Marine Biological Survey of Transects
Location of Proposed East Arm Port
Locality Plan
New Darwin Port, East Arm, Development Covered by E.I.S.
Plan of Existing Port of Darwin
Factors Controlling Location of New Port
Broad Development Concept
"Ultimate" Development of Port
Stage 1 Configuration
Stage 2 Configuration
Stage 3 Configuration
Stage 4 Configuration
Alternative Development Staging - Stage A
Stage B and Beyond
East Arm Port - Area of Cut
Land Systems and Geology of Quarantine Island and the East Arm Islands (Source: Acer Vaughan, 1990a, Fig 3).
Vegetation Communities of East Arm Peninsula (Source: Acer Vaughan, 1990a, Fig 4).
Patterns of Zonation in Mangroves (Source: Acer Vaughan, 1990a, Fig 5).
Vegetation Communities of the East Arm Islands (Source: Acer Vaughan, 1990a, Fig 6).
Sediment Distribution (Source: Acer Vaughan, 1990b).
Hydrodynamic Model Predictions for Existing Conditions and Final Development - Spring Tide Velocities for High Tide + 4 hours
Hydrodynamic Model Predictions for Existing Conditions and Final Development - Spring Tide Velocities for Low Tide + 4 hours
Sample Contour Plot of Suspended Solids Concentrations During Construction of Final Development
Location of Hard Seabed Survey Sites in Darwin Harbour
Location of Hard Seabed Survey Sites in Vicinity of Proposed Port.
Colour Infra-red Air Photograph of Study Area.
Pattern of Vertical Zonation of Hard Seabed Biota with Depth.
Depth of Sampling Points at Survey Sites
Distribution of Marine Biota at Survey Sites
Cluster Analysis of Biota at Survey Sites
Aboriginal Archaeological Sites
Heritage Sites
APPENDICES

Appendix A. Terrestrial Plant Species List (Source: Acer Vaughan, 1990a).

Appendix B. Vegetation Communities of the East Arm Peninsula and Shell Islands (Source: Table 5, Acer Vaughan, 1990a).


Appendix E. Mammals and Reptiles Recorded at Proposed Supply Base Site in June 1990 (Source: Acer Vaughan, 1990a).

Appendix F. Hydrodynamic and Sediment Model Results

Appendix G. Aboriginal Archaeological Investigation - East Arm Port Development, Darwin Harbour (Author: K Mulvaney).

Appendix H. Heritage Assessment - East Arm Port Development EIS (Author: P Dermoudy).

Appendix I. Extracts from World News page of the Melbourne "Age" relating to the WW II commando raids on Singapore Harbour launched from the LMS base on Quarantine Island.

Appendix J. Bird Count
## ACRONYMS

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<td>Australian Height Data</td>
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INTRODUCTION

The Northern Territory Government announced in August 1992 that additional port facilities would be built at East Arm in Darwin Harbour. Expansion of the port has been a long term goal of the Territory Government since self-government was achieved in 1978. It has been designed to make provision for the long-planned Darwin to Alice Springs railway line and represents a major step in the Government’s strategy to ensure that Darwin plays an increasingly important role in Australia’s trade with nations in the rapidly expanding Asia Pacific region.

The new port is to be located within an area which is the subject of preliminary land use investigations associated with the "Darwin South Project". However, the Government has made no commitment to proceed with any significant components of the Darwin South Project apart from the proposed East Arm Port. Therefore, this EIS considers the environmental implications of the port proposal in the light of existing conditions in the Darwin South area, and any subsequent proposals associated with "Darwin South" will be subjected to separate environmental assessments, which will have to take account of the any pre-existing and approved port facilities.

Preparation of EIS

A considerable amount of information on existing environmental conditions in the general vicinity of the new port has been collected over the past 15 years, most recently in connection with a proposed Darwin Offshore Supply Base (the ADDCAP proposal). This information was supplemented by the following investigations which were carried out as part of the EIS and port design programme.

- mathematical modelling of the effects of the port on currents and sediments;
- geotechnical investigations of both terrestrial and marine areas in the vicinity of the port;
- marine biological surveys;
- assessment of the significance of the area for birds;
- a heritage assessment; and
- an archaeological survey.

Draft EIS - Darwin Port Expansion East Arm - 1 - Acer Vaughan/Consulting Environmental Engineers (AV/532)
During the initial stage of the EIS process, contact was established with a range of organisations having particular interests in the implications of the port relocation proposal to: (1) provide them with an initial overview of the proposal; (2) identify any specific concerns; and (3) identify additional sources of relevant data.

NEED FOR PROPOSAL

Section 2 of the EIS reviews the nature of the existing Port of Darwin, the present and projected demands on the port, and the port facilities and associated infrastructure which will be required to meet future needs.

The existing port is situated adjacent to the Darwin CBD and consists of three discrete "pylon style" wharf structures comprising the Stokes Hill Wharf, the Fort Hill Wharf and the Iron Ore Wharf, together with a "roll on - roll off" facility.

The East Arm port expansion is designed to be a world class facility integrated with the proposed rail link. It’s construction is seen as a major step towards constructing the full 'landbridge' link.

OPTIONS CONSIDERED

Section 3 reviews the options which were considered by the NT Government in the process of arriving at its decisions to: (1) locate the new port at Quarantine Island in East Arm; (2) opt for a land-backed port configuration.

"No Action" Option
The "no action" option is incompatible with the Government’s plans to develop Darwin as a major trade centre serving the Asia Pacific region, as the present site cannot support a major port, nor is it likely that a satisfactory rail link through urbanised areas could be re-established to the existing port area. There are also a number of important planning considerations which make any significant expansion of the existing port facilities inappropriate.

Siting of New Port
The main considerations in selecting the general location of a new port in Darwin are as follows:

• good access to deep water;
• good access for a future rail link from the south;
• ample room for development of a major port;
• good access to existing industrial areas; and
• adequate separation from sensitive land uses.
The options for siting a major new port in Darwin Harbour are extremely limited. Quarantine Island in East Arm is the only location within the harbour which meets these requirements.

**Nature of Proposed East Arm Port Facilities**

The proposed port will involve the construction of a land-backed port extending out from Quarantine Island towards the main East Arm channel (to the west of the Shell Islands). Dredging of a channel, swing basin and both deep water and shallow berths will provide fill for the project, as will rock and soil materials excavated from Quarantine Island. This design was selected by the Department of Transport and Works (T&W) as its preferred option following a review of a wide range of possible configurations involving various combinations of dredging, filling and piled structures.

The selected port concept was strongly influenced by advice from the DPA and the shipping industry to the effect that a fully landbacked design, complete with extensive onshore areas reserved for port-related activities, is essential if the new port is able to be cost-competitive with other modern ports. This design maximises accessibility between ship unloading cranes and the container storage area.

A further important consideration in the selection of the site and the design of the berths, turning basin and channel is the effect of the existing bathymetry and the port configuration on current speed and direction. The proposed concept seeks to optimise the orientation of the channel to achieve current flow as close as possible parallel to its centre line, and to the berths.

The main elements of the "ultimate" port concept are as follows:

- A container terminal comprising a 900 m long container berth complete with container cranes and backed by a 42 ha container handling yard.
- A rail container terminal will adjoin the northern edge of the container yard and a rail reserve around the western shore of Quarantine Island will provide access to a future Berrimah rail freight terminal.
- A general port area will include provisions for a heavy lift crane, and the loading and unloading of minor bulk cargoes, livestock and other general (non-containerised) cargoes. An overhead conveyor will connect the minor bulk berth to the Northern Cement plant.
- A 58 ha future port usage area will be reserved for such uses as the berthing and maintenance of smaller commercial and fishing vessels and a supply base for off-shore petroleum exploration and production.
- Most of Quarantine Island will be levelled and reserved for port-related industries.
- Provision has been made in for a possible future major bulk cargo facility in the area between the proposed container port and the western shore of...
Quarantine Island.

- A public boat ramp and parking area will be included in the development.

Staging of Development
The pattern of development of the new port will need to be flexible in order to respond to the growth in specific types of cargoes and port-related industries. It will be constructed in stages in response to demand.

PROJECT DESCRIPTION

Section 4 of the EIS provides a broad overview of the proposed port, the proposed construction methods, the changed function of the existing Port of Darwin, and operation of the proposed port. However, specific details of many aspects of the project have yet to be clarified.

Construction Process
Construction of the main port area will involve the following steps:
- construction of bunds using material excavated from Quarantine Island;
- placement of armour rock on the outer faces of the bund using largely imported quarried materials from commercial quarries;
- filling the area within the bunds with a combination of dredge spoil and material from Quarantine Island; and
- construction of the wharf front.

Dredging of the channel and swing basin will be undertaken using a cutter-suction dredge, and all dredge spoil will be deposited within the bunds forming the perimeter of the development as described above. A decant arrangement will apply in the reclamation area to separate the dredged fill and water before the return of dredge water to the harbour.

There will be a shortfall of approximately 1.25 million cubic metres of fill for the ultimate development (without major bulk port). The source of the material to be used in this aspect of construction has not been specified and therefore cannot be examined by this EIS. A separate environmental assessment may be necessary to define the effects of this operation if and when these works are to be undertaken.

The first contract (Stage 1 bund and access earthworks) is scheduled for late February 1994.

Revised Function of Existing Port Facilities

Activities to be transferred to the new port upon the commissioning of Stage 1 include all container traffic and the handling of livestock and cement clinker. However, it is not planned to relocate the existing bitumen plant, cement silos, lead...
and zinc loading facilities or the existing "roll on / roll off" facility at this stage.

Further development of the existing port precinct recreational and tourist features will occur following the progressive transfer of port functions from the existing port site. These developments are currently in the preliminary planning stages but plans include construction of a swimming area, grassed areas, food outlets and walkways.

Operation of Proposed Port
All major shipping traffic will be confined to within the natural and dredged channels. Berthing and unberthing manoeuvres will need to take account of eddys and tidal currents in the channel and swing basin, which are predicted to reach 4.0 knots (1.8 m/s) during spring tides.

The existing port operation involves the use of one tug boat and the services of two pilots. The need for more pilots is not envisaged for Stage 1 of the project; however, additional tugs will in due course be required for the berthing of large vessels at the new port.

It is envisaged that regular maintenance dredging will be required, at least during the early years of the port, to remove sand and gravel which will tend to be deposited in the dredged areas from the surrounding channel deposits. Spoil material arising from maintenance dredging will provide good quality fill for progressive construction of the hardstand areas of the new port.

EXISTING CONDITIONS AND ENVIRONMENTAL EFFECTS

Section 5 of the EIS describes existing conditions (based on both available information and the results of the EIS investigations) and assesses the potential environmental effects of the proposal.

Terrestrial Environment
The terrestrial environment includes those parts of the study area which are above the high tide mark (for convenience, all birds are included also in this section).

Existing Conditions. The terrestrial environment has been extensively modified by human activity and its biological systems are well represented in the region. Quarantine Island has a high density of biting midges; however, there are no large mosquito breeding sites in the immediate vicinity.

North Shell and Catalina islands provide minor, but significant high-tide roosting sites for a number of species of birds, including three listed vulnerable species: the Terek Sandpiper; Little Tern and Beach Thick-knee (Stone Curlew).
Environmental Effects. The project will result in the removal of elevated sections of Quarantine Island, along with essentially all of the existing terrestrial vegetation and faunal habitats.

The removal of vegetation, coupled with the disturbance associated with extraction of construction material, will increase the potential for erosion during the wet season, which will lead to increased sediment loads on adjoining sections of East Arm. The impact of the loss of terrestrial vegetation (and hence faunal habitat) from Quarantine Island is considered to be relatively insignificant in the regional context.

The port will ultimately be extended to cover North Shell Island, at which time the latter will cease to be available as a minor high tide roosting area for birds, including migratory waders and vulnerable species such as the Terek Sandpiper, Little Tern and Beach Thick-knee. The availability of other broadly similar roosting sites in the Darwin region suggests that the loss of North Shell Island should not have a major impact on any bird species, although a monitoring programme should be established to clarify this issue.

Maintenance of a waterway between the port and Catalina Island should help to ensure that port activities do not intrude onto Catalina Island.

Estuarine Physico-chemical Environment
The East Arm of Darwin Harbour is the estuary of the Elizabeth River and experiences significant daily and seasonal fluctuations in salinity and turbidity.

Existing Conditions. Bathymetric surveys suggest that the bathymetric regime of East Arm has been relatively stable over at least the past 20 years. The main channel of East Arm maintains a clear depth of at least 15 m between the existing port and for a short distance after it passes to the south of South Shell Island. From this point the channel depth decreases progressively to about 2 m at a point to the south of Hudson Creek.

North Shell Island has a maximum elevation of 2 m above high water, while South Shell Island is completely covered during high tides. There is a relatively narrow 2 m deep channel between the Shell Islands. Most of the area between North Shell Island and Quarantine Island which is to be filled to create the proposed port dries at extreme low tides.

Sediments in the channels in the vicinity of the port are composed predominantly of coarse to medium grained gravels (2 to 10 mm). An extensive area of sand forms a large sandbar which extends about 4 km up East Arm from South Shell Island. Marine sediments in most areas outside the main channel consist of fine material
(described generally as "mud") comprised of clay and silt. Sediments in areas which are to be dredged appear to contain only a very small proportion of fine material. The reef area between Quarantine and North Shell islands which will be covered by the proposed port has little or no mud cover.

The tides at Darwin are among the largest on the Australian coast, and the tidal water movement has a large influence on the shape, seabed characteristics, current dynamics and water quality of Darwin Harbour.

A two-dimensional computer model developed by Acer Vaughan/Patterson Britton was used to predict current patterns in East Arm with and without the proposed port. The model was calibrated and verified by a series of field studies during January and April 1993.

During spring tides the peak inflowing current is 0.6 to 0.9 m/s throughout the channel in East Arm. The current speed exceeds 0.9 m/s in the channel southeast of South Shell Island, and in the narrowing southward channel leading to the Elizabeth River. During Spring tides the peak outflowing current is 0.6 to 0.9 m/s throughout the channel of East Arm. The regions where outflowing current speeds exceed 0.9 m/s are to the southeast of North and South Shell Islands, and in the narrowing southward channel leading from the Elizabeth River. Some of the mangrove creeks extending off the main channel of East Arm also have relatively fast currents, generally peaking at around 0.6 m/s on spring tides.

The water quality parameter of most relevance to the East Arm Port proposal is turbidity, which is an important controlling factor in the distribution of marine organisms. Turbidity in the harbour varies greatly from site to site and season to season, with the highest values during the wet season, in the middle reaches of East and Middle Arms where high tidal currents generate turbulence which tends to resuspend particular matter from the bed of the estuary.

**Environmental Effects.** The mathematical model predicts that peak flood tide current speeds at ultimate development of the port will exceed 0.9 m/s beside the wharf, and in the narrowing southward channel leading to the Elizabeth River. No significant changes would occur in currents southeast of South Shell Island, where the peak current speed decreases due to the larger channel area available. There will also be weaker currents to the northwest of the port, and generally sedimentation in these areas over time is expected. Tidal excursions in East Arm will decrease slightly, but this will not have any significant effect on dispersion or tidal flushing.

The model predicts that the presence of the port will result in weaker currents in the vicinity of South Shell Island during ebb tides, but a peak current of 1.2 m/s beside the wharf.
The promontory located approximately 4 km southeast of the Quarantine Island boat ramp (referred to hereafter as the southeast promontory) will experience higher current speeds, particularly on the ebb tide. There also is predicted to be a significant shift in current patterns, and an increase in current speeds in the mangrove creeks south of the port (in the Paspaley Pearling Lease area). These will alter sediment patterns in that region, and increase the rate of erosion of the southeast promontory.

Concern has been expressed by the Aboriginal Areas Protection Authority regarding the influence of the East Arm Port project on the sandbars around Catalina Island, which is about 750 m southeast of Quarantine Island. Predicted increases in tidal velocities east and south of the Catalina Island have the potential to scour the sand bars. Further investigations of the shoals around Catalina Island should be undertaken to confirm the sediment characteristics and potential for scour.

Construction of the port will involve increased sediment loads on East Arm from the dredging and construction activities. The behaviour of this suspended sediment plume was modelled to identify its path and its influence on background suspended solids concentrations in East Arm. Suspended solids concentration contours were produced for a simulated six day period for a spring tide for the Stage 1 and Ultimate Development scenarios.

The results of the sediment modelling suggest that the sediment plume would tend to disperse to a large degree within the upper part of East Arm, although the increase in suspended solids concentration on the southern side of East Arm (in the vicinity of the Paspaley Pearling lease) would be much smaller than the values near the port site. The concentrations in this area are highest during an ebb tide, and appear to gradually increase with time. With continuous dredging over several months, it can be anticipated that the whole of East Arm upstream from the port will have higher turbidity concentrations for both Stage 1 and ultimate development, assuming similar extended dredging activities are involved in each stage.

In summary, the port will alter current patterns in East Arm and there will be a gradual change in sediment distribution to a new equilibrium. A slow rate of change is expected because there is only a small supply of sediment to East Arm. As fine sediments in the harbour tend to contain low levels of metals (of natural origin) slightly elevated heavy metal concentrations can be expected to be associated with elevated turbidities.

**Estuarine Biological Environment**

A number of marine biological studies were undertaken as part of the EIS programme, and assesses the likely environmental impacts of the construction and operation of the port facility on the marine biota.
Existing Conditions. The major physico-chemical conditions affecting the distribution and condition of existing marine biota in the East Arm and elsewhere in Darwin harbour are the large tidal variation, seabed composition, water depth and water quality. Darwin Harbour supports a diverse mix of tropical marine and estuarine biota, as summarised below.

• **Mangrove Communities.** The mangroves of Quarantine Island occupy well defined zones which are related to the level of the substrate and the frequency of tidal inundation. Significant areas of the mangrove areas on the island consist of salt flats, which are largely devoid of vegetation, and numerous bare areas resulting from cyclone damage.

• **Soft Seabed Biota.** There are extensive areas of intertidal mudflat in Darwin Harbour, which are inhabited by burrowing invertebrates including worms, small crustaceans and bivalve shellfish. Generally the diversity and abundance of these fauna in the intertidal mudflats appears to be low compared with the fauna of the muddy seabeds below the low tide mark.

• **Fish.** The reefs, channels and coral and sponge gardens in the vicinity of the Shell Islands provide diverse habitats for fish. The fish species associated with the Shell Islands should be similar to those found elsewhere in Darwin Harbour although the proportion of species present at each site is likely to vary according to the habitat characteristics.

• **Plankton.** Although it is widely recognised that mangrove leaf fall represents the major source of organic material for the Darwin Harbour ecosystem, phytoplankton (microscopic plants) are also an important primary producer. Plankton in the main channels of East Arm are mostly likely to be of oceanic origin, with a smaller contribution from the mangrove creeks and inlets.

• **Hard Seabed Biota.** Darwin Harbour supports an abundant and diverse range of biota associated with the rocky and coral rubble seabeds including corals, fish, sponges, anemones and gorgonians. The reefs are scattered throughout Darwin Harbour, and provide a habitat for small fish which are preyed on by larger fish such as jewfish, barramundi, snapper and sharks.

The corals and shallow reef communities in Darwin Harbour are an important component of the Harbour's ecosystem, but it is apparent that their distribution is limited by natural factors including: (1) availability of suitable substratum; and (2) low light penetration due to high turbidity. The high turbidity limits most benthic plant and coral growth to approximately 7 m below mean sea level. Hence the corals and associated flora and fauna are only found in abundance on suitable seabed, and in the relatively narrow 3 to 4 m depth zone below the low spring-tide mark. Below this depth,
sponges and gorgonians and other organisms which do not require light for photosynthesis are dominant.

Marine biological studies during the EIS focussed on the hard coral zone since this was considered by local marine biologists and naturalists to be the most limited biological assemblage in the harbour. During the studies, marine biologists dived at a total of 28 sites in Darwin Harbour over two 4 day periods of neap tides from 16 to 21 May, and 12 to 15 August 1993.

Biological communities inhabiting the hard seabed around South and North Shell Islands comprise a diverse range of hard coral, soft coral, algae and other invertebrate species. Although each of the sites surveyed was characterised by a unique combination of flora and fauna, a generalised depth-related pattern of distribution was discernible.

There was a high degree of variation in the characteristics of the biological assemblages based on the combinations of coral species at each site, which presumably reflects habitat variation (eg. seabed profile and composition, current regime, ambient water turbidity). In spite of this variation, most species appeared to be represented at most sites. Thus the Shell Islands appear to have a lower abundance and diversity of plate forming hard corals, but a higher abundance of exposed rubble which provides habitat for a variety of other invertebrate species which may be found in lower abundance at other sites.

Marine Mammals. Little is known about the importance of Darwin Harbour for marine mammals. Dolphins are occasionally sighted in Darwin Harbour and are most likely to be simply transiting. Dugongs are herbivorous marine mammals and have been detected in Darwin Harbour at low to moderately high densities. As Dugongs feed almost exclusively on seagrasses they are unlikely to be dependent on East Arm as it is not known to contain any significant areas of seagrasses.

Marine Reptiles. Several species of turtles have been recorded from waters of Darwin Harbour, including Green, Flatback and Hawksbill turtles. Flatback turtles are known to breed occasionally at Channel Island and Mica Beach in Darwin Harbour; however, there are no records of turtle breeding on North Shell Island. Saltwater crocodiles inhabit the tidal rivers and open water of Darwin Harbour. Various species of sea snakes are common around the mangroves, mudflats and open waters of Darwin Harbour.

Environmental Effects. Construction of the proposed port will directly result in the loss of a relatively small area of mangroves, amounting to only about 8 ha.
This area represents only about 0.04 of the total 20,000 ha area of mangroves in Darwin Harbour. It is recognised that the environmental value of mangroves cannot be quantified solely on an areal basis without reference to the structure and productivity of mangroves and associated fauna. Therefore, as about 30 per cent of these mangrove areas consist of low productivity zones such as salt flats and bare mud resulting from cyclone damage, it may be concluded that the loss of these relatively small areas of mangroves would have no detectable effect on the overall diversity or productivity of mangroves in Darwin Harbour.

The modified current regime in East Arm resulting from the Stage 1 construction and dredging works is expected to result in progressive siltation of the area designated for possible future bulk cargo rail loop, eventually leading to the creation of an enlarged mangrove zone (with some loss of existing mangroves on the western shore of Quarantine Island as the surface of the sediments rises). It is not possible at this stage to predict whether the redistribution of sediments in East Arm “upstream” from the new port will result in any changes in mangrove distribution, although any such changes are unlikely to be significant in the context of the overall harbour.

Construction of the port will have a relatively short term effect on fish. Large pelagic species (e.g., great trevally, jewfish and queenfish) have been observed around the existing port, and the existing Darwin port area is a popular fishing location.

Planktonic biota may be affected by increased turbidity during the construction period. A small proportion of the plankton may be more directly affected by entrainment by the dredge. However, due to the regular and large tidal exchange of plankton with the adjacent Beagle Gulf, impacts on plankton will be localised and relatively short term.

The construction of the port will have major direct and indirect effects on benthic (bottom-dwelling) biota as most of the particular biological associations at North Shell and South Shell Islands will be lost as a result of the construction of the Port. As discussed above, the marine biological communities in this area comprise a diverse assemblage of hard and soft seabed biota. However, the individual biological taxa presently found in the affected areas are likely to be represented at other hard and soft seabed habitats at other locations in Darwin Harbour (e.g., Middle Arm).

Construction and the subsequent redistribution of sediments upstream from the port will have a more widespread, indirect effect on benthic biota due to increases in turbidity and sediment loads. As the distribution of many species appears to already be limited by turbidity and blanketing by sediment, these effects could be significant for the hard seabed biota closest to the new port, such as remaining...
communities at South Shell Island and Old Man Rock. The degree and extent of these effects cannot be defined at this stage, as the nature of the dredging and marine construction techniques have yet to be determined. Monitoring of biota will be required to assess these impacts and determine whether additional measures should be implemented to minimise construction impacts.

Construction of the port will have short term effects on marine mammals and reptiles in the vicinity of the new port.

The effects of the operational phase on the marine environment may be considered in terms of: (1) increased human and shipping activity; (2) ongoing physical changes due to the reconfiguration of the major channels and barriers to water movement; and (3) the potential for discharges of toxic materials as the result of normal or abnormal port activities. Measures are available to minimise the likelihood of significant effects resulting from port operations.

Visual and Acoustic Environment

Visual and acoustic factors are considered together as they both contribute to the aesthetic character of the study area.

Existing Conditions. The predominant landscape elements of East Arm are the water, the fringing mangroves and extensive areas of tidal mud flats (at low tide). There are few vantage points, apart from on the harbour itself, which provide clear views over the proposed port area.

No noise surveys have been conducted in the area of the proposed port. However, the existing acoustic situation is simple, with the Northern Cement Plant and associated truck traffic being the only significant noise source which intrudes on an otherwise low background noise environment.

Environmental Effects. The most prominent visual signs of the construction activity, as viewed from vantage points in the city area and from boats on East Arm, will be the removal of vegetation and earthworks on Quarantine Island, and the construction of temporary bunds and wharf front to form the port area. These will be low in elevation however and will not be a significant visual intrusion. The remoteness of the site from residential areas will generally ensure that construction of the port does not cause noise problems.

The most visually-prominent features of the operating port will be the presence of vessels, container cranes and containers stacked on the hardstand. Most observers are likely to consider the port as a matter of interest, and an elevated viewing point on the edge of the port is provided as part of the project to allow interested members of the community to view the developing site. Noise generated
by port operations will generally be limited to engine noise from ships, trains, forklift trucks, heavy vehicles, conveyor systems, and the handling of general cargoes. None of these should be perceptible in any existing residential areas.

**Historic and Archaeological Factors**

Investigations were carried out to assess archaeological and historic features within the study area.

**Existing Conditions.** The Aboriginal Archaeological Investigation positively identified the following features associated with earlier Aboriginal occupation of the site:

- an extensive shell midden in the vicinity of the existing (Catalina) boat ramp;
- a sparse shell "scatter" just above the high tide mark, immediately west of the Northern Cement property;
- a shell midden, together with two lumps of quartz each of which appears to have a single flake scar, on the northern tip of Catalina Island; and
- two isolated artefacts (flaked stone points) near the higher sections of Quarantine Island.

Of the three confirmed Aboriginal shell middens, the large midden near the Catalina ramp was judged to be of the greatest significance, and its potential research value to be high, although other similar sites have been documented along the Darwin Harbour coast line. The Aboriginal Areas Protection Authority has advised that there is a sacred site on Catalina Island and its adjoining sandbar which must not be disturbed.

The heritage assessment of Quarantine Island concluded that the sites associated with the WW II "Lugger Maintenance Section" (LMS) must be considered as being of high significance in terms of a range of Criteria for the Register of the National Estate. The report indicates that the LMS relics and the area which contains them are of National and International significance, and that their heritage value can be expected to increase with time.

There are a number of ship and aircraft wrecks in Darwin Harbour, which have historic value and also serve as artificial reefs. The wrecks include a number of Catalina flying boats lost during WW II. Of these, two are known to be affected by the proposed port works. The Heritage Unit of CCNT has confirmed that while the Catalina wrecks are of some historic interest, none of them has been formally assessed by CCNT to date, nor do they have a protected status.
Environmental Effects.

Archaeological Sites: The proposed Stage B as depicted in Figure 3-9, will require the removal of the shell middens identified in 5.5.1. The Proponent proposes therefore that, as recommended by Mr Mulvaney in this event, these middens be assessed in detail prior to construction so as to record their pre-historical significance.

Sites of Significance to Aboriginal People: The Proponent will comply with the requirement of the final Authority Certificate in respect of the Catalina Island sacred site.

Historical Site: At this stage the status of the LMS base has not been listed on the Register of Heritage Places. In accordance with the NT Heritage Act interested parties can submit a proposal to the Heritage Advisory Council for the site to be listed. At the time of writing, it is understood that a process has been set in motion to address this matter. After due process the Advisory Council will make recommendations to the Minister for his decision. If the site is then listed, gazetting and preparation of a Conservation Management Plan will follow. In the event that the site is listed the Proponent will ensure that the gazetted area is secured and protected in accordance with the requirements of the Conservation Management Plan.

Historical Wrecks: Catalina flying boat wrecks at two locations will be effected by the works. At the time of writing discussions were ongoing between the Proponent and the Australian Navy and the Aviation Historical Society in order to determine the most appropriate means of dealing with the wrecks. The Proponent undertakes, to assist in relocating/salvaging the wrecks in accordance with the agreed resolutions of these discussions.

Regional Planning and Socio-economic Considerations

The proposed port relocation has important implications for regional planning, development in the Darwin region and for a number of existing activities in the harbour.

Existing Conditions

As there are no feasible alternative sites for the proposed port relocation, strategic plans for Darwin’s future growth have for many years provided for the eventual transfer of port operations from the Stokes Hill/Fort Hill area to the proposed East Arm location.
Two commercial pearl culture operations are conducted in areas of East Arm leased from the NT Government by the Paspaley Pearling Company Pty Ltd and South Sea Pearling Pty Ltd, respectively. The 15 year Paspaley lease has been in force since 1983 over an area of 335.5 ha on the southern side of East Arm, which takes in a 2.5 km long section of the main channel and extends about half-way up two adjacent mangrove creeks. Paspaley Pearling now uses its East Arm lease for "resting" juvenile oysters before they are transferred to the Company's growing-out leases on the Coburg Peninsula. Approximately 24,000 young oysters are rested in East Arm each year between November and the following July.

Indo Pacific Marine operate innovative and impressive displays of local marine life in an aquarium adjacent to the Stokes Hill Wharf. The display is a popular tourist attraction, as it enables visitors to observe, under ideal viewing conditions, literally hundreds of different species of marine organisms living and feeding together. The proprietors have a permit from the Fisheries Division to collect marine organisms to establish and restock the displays as required. Their principal collecting area is the reef area which extends between Quarantine and North Shell islands, as this area supports very diverse marine life and can be readily accessed on foot at low tides. All of this reef area will eventually be covered by the proposed port development.

Darwin Harbour is a popular location for recreational fishing and boating, while a number of clubs and commercial operations conduct SCUBA dives at a number of locations.

The ready accessibility of North Shell Island from the Quarantine Island boat ramp and its beaches make it a popular picnic site for boating enthusiasts (as noted earlier an apparent reduction in the number of birds roosting on this island has been attributed to increased visitation).

Environmental Effects. The project should not require any significant influx of personnel or produce any significant additional demands on existing housing, urban infrastructure or community support services.

Indo Pacific Marine will be inconvenienced by the port proposal, from the time when marine construction work commences, because of the loss of their main collection area which is currently accessed on foot.

Expected increases in suspended solids concentrations in the general vicinity of the two commercial pearling leases could be expected to have some effect on pearl oysters, which rely on filtering microscopic food particles from the water column. It is not possible, on the basis of available information, to predict the extent to which suspended solids concentrations are likely to be increased in the vicinity of the leases, or whether such changes are likely to adversely affect the pearl culture operations.
The fact that the proposed East Arm Port has been accepted for many years as an important element of Darwin's future infrastructure means that its operation is unlikely to have any unexpected effects on the pattern of development of the Darwin region; rather, it represents a key Government initiative to stimulate the NT economy.

The transfer of certain port operations from the existing location to the new port will not in itself have any effect on the overall level of economic activity; however, it will provide a range of significant benefits including:

- creating redevelopment opportunities for the existing port area;
- redirecting heavy truck traffic associated with port operations away from the vicinity of Darwin city centre; and
- stimulating the development and expansion of port-dependent industrial and commercial activities in the TDZ and Berrimah industrial areas.

The expectation that a rail terminal and cargo interchange will be developed later at the East Arm Port, aimed at attracting a significant share of the container traffic which currently passes through ports in the southern and eastern States, has the ability to greatly increase the level of economic activity in Darwin.

The proposal is unlikely to have a significant impact on recreational use of East Arm for fishing, particularly as a new public boat ramp is to be included in the project. While some existing fishing spots will be lost or modified, the port structures should compensate for the loss of reef area as a habitat for reef organisms and fish.

Most of the commonly used SCUBA dive sites in East Arm will be lost or significantly modified as a result of the proposal (refer to Section 5.3). However, the rich coral reefs identified in Middle and West Arms of the harbour as part of the investigations for this EIS, will provide other options for such dives.

The ultimate loss of North Shell Island which currently provides one of the few significant firm high tide beach areas in the harbour will reduce the range of recreational boating activities.
ENIRONMENTAL SAFEGUARDS AND MONITORING

Section 6 reviews a range of environmental safeguards which may be adopted to minimise the potential effects of the proposal.

Monitoring of specific sectors of the environment is often warranted during the construction and/or operational phases to: (1) provide more precise information on the nature of potential impacts which cannot be precisely predicted; (2) ensure that the safeguards are appropriate (experience may show that some are not required, while others may need to be strengthened); and (3) enable the design and construction of subsequent development stages to be refined to further minimise impacts.

Environmental Safeguards

Many of the environmental safeguards identified below as being appropriate for the proposal are, of necessity, "generic" in nature and may need to be refined at a later date when more details of the project become available.

The EIS defines the objectives and nature of environmental safeguards which should be applied to the earthworks on Quarantine Island and the stabilisation of disturbed areas pending industrial development.

The main safeguards which can be applied to minimise the impacts of construction on the estuarine environment are concerned with reducing suspended solids loads on East Arm by: (1) the adoption of good construction practices in disturbed areas of Quarantine Island; (2) use of a shroud on the cutter/suction head of the dredge(s) to minimise the loss of fine sediments; (3) reducing the concentration of suspended solids in the dredge return water to East Arm by maintaining adequate detention within the bunded port construction area; (4) maintaining a zone of armour rock on the outer face of the bunds during their construction (by zone tipping) to minimise erosion of the bunds by currents and wave action.

In view of the remoteness of the port site from areas frequented by the public, no special provisions should be required in relation to the appearance of the works during construction.

Noise emissions from heavy earthmoving equipment, such as bulldozers and scrapers, are not expected to be detectable in residential areas, which are about 5 km away.

Construction of the new port will provide a small stimulus for economic activity in the region, although it should not impose any significant strains on the local labour
market, community support services or urban infrastructure. Therefore, no specific measures should be required in this regard.

A range of measures can be used to minimise the effect of dredging on suspended solids concentrations in East Arm and other sections of the harbour. However, Paspaley Pearling personnel have indicated that the pearl culture operations in East Arm may be scaled down, as a precautionary measure, until any effects on the oysters have been established.

Facilities and procedures for handling any potentially hazardous materials will comply with the Association of Australian Port and Marine Authorities standards, while the land transport of such materials must be undertaken in accordance with NT Work Health Authority requirements.

Air quality guidelines have yet to be adopted for the Territory; however, CCNT will assess the air quality implications of all proposals to establish industries in the port area at the planning approval stage in accordance will prevail National Health and Medical Research Council guidelines.

Any potential risks of shipping accidents during berthing or unberthing manoeuvres should be investigated by carrying out navigation simulations using the predicted current conditions to identify envelopes of difficult or dangerous tide flow situations for specific types of vessels, so that these conditions can be avoided.

The provision of appropriate bunding around storage facilities for bunker oil and potentially toxic chemicals passing through the port should ensure that any spills can be contained and no significant discharges of contaminated runoff to East Arm occur. The storm water drainage system will be discharged through appropriate interception systems as necessary.

Measures will be required to minimise the discharge of antifouling paint scrapings from ship repair facilities to East Arm. This can be achieved by providing specific areas equipped with traps for scraping down vessels.

**Monitoring**

Monitoring of specific effects is warranted during the construction and/or operation of major projects such as the East Arm Port to: (1) provide more precise information on potential impacts which cannot be precisely predicted; (2) ensure that the safeguards are appropriate (experience may show that some are not required, while others may need to be strengthened); and (3) enable the design and construction of subsequent development stages to be refined to further minimise impacts.

The monitoring programme undertaken by the Proponent will be devised with the
The monitoring programme during construction will concentrate on:

- inspections of the terrestrial environment to ensure that erosion controls are exercised and that any protected historical/cultured sites are secured;
- bird counts on North Shell Island;
- the extent and intensity of sediment plumes, sedimentation, scour and biological effects in the estuarine environment.

During operations a monitoring programme to identify whether measurable waste loads are generated in East Arm by the port development will be conducted.

INFORMATION SOURCES AND COMMUNITY CONSULTATION

Section 7 reviews the sources of information used as a basis for preparing the Draft EIS and identifies community organisations consulted during the course of this assignment.
DRAFT ENVIRONMENTAL IMPACT STATEMENT
- DARWIN PORT EXPANSION -
EAST ARM

1. INTRODUCTION

This chapter summarises the objectives of the Darwin Port Expansion Proposal, the scope of this Draft Environmental Impact Statement (EIS) and the steps involved in its preparation. The EIS has been prepared on behalf of the Proponent, the Northern Territory Government's Department of Transport and Works, by the consulting team of Acer Vaughan and Consulting Environmental Engineers.

1.1 OBJECTIVES OF PROPOSAL

The Northern Territory Government announced on 5 August 1992 that additional port facilities would be built at East Arm in Darwin Harbour. The East Arm Port, which is to be constructed in several stages, will have the potential to handle projected volumes of general cargoes, livestock and bulk materials for at least the next fifty years. However, bulk petroleum shipments will continue to be received at the Fort Hill berth and stored in the existing tanks, pending the likely future development of a new oil berth and tank farm (neither of which forms part of this proposal).

Expansion of the port has been a long term goal of the Territory Government since self-government was achieved in 1978. It has been designed to incorporate the long-planned Darwin to Alice Springs railway line, which would link the port to the national rail system. Construction of the additional port facilities will represent a major step in the Government's strategy to ensure that Darwin plays an increasingly important role in Australia's trade with nations in the rapidly expanding Asia Pacific region, as typical sailing times from Darwin to Singapore and Japan are only five and seven days, respectively.

The progressive relocation of the existing industrial port activities to East Arm will provide a range of opportunities for redevelopment of the existing Port Darwin area as a commercial and tourist precinct linked to the CBD, a process which has already begun. The East Arm port is also expected to promote the level of business and industrial activity in the Trade Development Zone (TDZ) on the East Arm Peninsula, which is Australia's only export processing zone.

As shown in Fig 1-1, the new port is to be located within an area which is the subject of preliminary land use investigations associated with the "Darwin South Project". Darwin South is still at the conceptual planning stage but incorporates the
proposed East Arm Port Facilities. It is important to recognise that with the exception of the East Arm Port, the Government has made no commitment to proceed with any significant components of the Darwin South Project. Therefore, this EIS considers the environmental implications of the port proposal in the light of existing conditions in the Darwin South area. Any subsequent proposals for other major components of Darwin South will be subjected to separate environmental assessments, which will have to take account of the any pre-existing and approved port facilities. Fig 1-2 shows the relationship of the new port to the existing port and the East Arm Islands. The project covered by this EIS is shown in Figure 1-3. This is essentially the scope covered by the East Arm Port Development Masterplan (Department of Transport and Works (1993)) but without the railway approach and bulk cargo loop (see Figure 3.3).

1.2 SCOPE OF EIS

This Draft EIS has been prepared to meet the requirements of the NT Environmental Assessment Act, which seeks to ensure that the environmental implications of proposed projects are considered in a balanced way during the design phase, so that any unnecessary and unacceptable harm to the environment can be avoided. The document is also intended to assist interested persons and organisations who wish to make submissions in relation to the proposal during the public review phase of the Environmental Assessment process.

It should be reiterated that this EIS does not include consideration of the overall Darwin South Project. As indicated above a subsequent EIS would have to be prepared before work on other elements of that project could proceed.

This Draft EIS includes the following main sections:

- **Need for Proposal.** This section describes: (1) the existing port facilities; (2) existing and projected demands for port facilities in Darwin; (3) the ability of the existing port to meet these demands; and (4) the port facilities and associated infrastructure required to meet the projected demands.

- **Options Considered.** This section reviews: (1) the options considered by the proponent, the Department of Transport and Works (T&W) during the process of identifying the location for the new port and its conceptual design; (2) the factors which were taken into account by T&W in selecting the port concept which is the subject of this Draft EIS; and (3) the implications of the "no action" option.

- **Description of the Proposal.** This section describes the proposed port relocation project in terms of: (1) the design of the port and associated facilities; (2) construction methods; (3) future uses of the existing port
facilities; and (4) the operation and maintenance of the new port.

- **Description of the Existing Environment and Environmental Effects.** This section describes the existing conditions and the projected environmental effects for all aspects of the natural, cultural and socio-economic environment likely to be affected by the proposal.

- **Environmental Safeguards and Monitoring.** This section identifies: (1) environmental safeguards which have been incorporated into the proposal to minimise the environmental impacts of the construction and operation of the port; and (2) a monitoring programme designed to evaluate the adequacy of these provisions.

### 1.3 PREPARATION OF DRAFT EIS

In March 1993 the Department of Transport and Works (T&W) accepted a joint proposal from Acer Vaughan and Consulting Environmental Engineers to prepare an EIS for its preferred East Arm Port concept. The consultant’s proposal recognised that a considerable amount of information on existing environmental conditions in the general vicinity of the new port has been collected over the past 15 years.

These investigations, which are summarised in the report on the Darwin South Baseline Studies Review (Dames and Moore (1992)), were conducted for a variety of purposes including: (1) developing guidelines for effluent disposal to East Arm; (2) monitoring of harbour water quality; (3) defining the importance of mangroves in Darwin Harbour and preparing a management strategy for their protection; (4) assessing the environmental effects of the (originally proposed coal-fired) power station on Channel Island (including monitoring the impacts of construction and dredge spoil disposal on marine biota); (5) identifying and recording historic and archaeological sites; and (6) investigations undertaken in 1990 in connection with the preparation of a preliminary environmental report (Acer Vaughan (1990a)) for a proposed Darwin Offshore Supply Base (the ADDCAP proposal).

The ADDCAP environmental report (Acer Vaughan 1990) drew together available information on the terrestrial and marine environments in the vicinity of Quarantine Island (the location of both the current East Arm Port and ADDCAP offshore supply base proposals) and detailed the findings of a number of field investigations carried out specifically for that environmental assessment. Although the ADDCAP report was not submitted as a formal report under the Environmental Assessment Act procedures, it was thoroughly reviewed by all relevant Territory Government Departments.
Departmental submissions on the ADDCAP report indicated that the baseline data provided an adequate basis for assessing the environmental effects of that proposal in respect of most sectors of the environment, while also suggesting that additional information was required in several other areas. Accordingly, additional field investigations were carried out during the preparation of this EIS to supplement the existing data base in these areas. This supplementary work was carried out by the EIS project team except where otherwise noted, and included the following tasks:

- additional investigations of current patterns in East Arm (carried out by Acer Vaughan/Patterson Britton under separate contract to T&W);

- mathematical modelling of the effects of the port and associated dredging on current patterns and sediment behaviour in East Arm (carried out by Acer Vaughan/Patterson Britton under separate contract to T&W);

- geotechnical investigations of both terrestrial and marine areas in the vicinity of the port to define the nature of sediments and rock, assess the techniques required for excavation and dredging, and the suitability of excavated and dredged material for use as armouring and fill (carried out by Dames and Moore under separate contract to T&W);

- marine biological surveys to identify the nature of the marine ecosystem and the diversity and abundance of biota as a basis for assessing the effects of the proposal on marine life;

- surveys of wading birds on the East Arm Islands; and subsequent

- assessment of the significance of areas likely to be affected by the proposal for feeding and roosting by birds (including migratory species covered by international treaties);

- additional investigations of the nature and significance of historic features on Quarantine Island associated with its earlier use as a quarantine station and for commando and catalina bases during WW II;

- an archaeological survey of Quarantine Island to identify and assess any archaeological sites; and

- application by the Proponent to the Aboriginal Areas Protection Authority to establish whether any sites of significance to Aboriginal people may be affected by the proposal.
During the initial stage of the EIS process, contact was established with a range of organisations having particular interests in the implications of the port relocation proposal. The main purposes of these preliminary consultations were to: (1) provide these organisations with an initial overview of the nature of the proposal and the time schedule for preparation of the EIS; (2) obtain information on any specific requirements or concerns which should be taken into account in preparing the EIS; and (3) identify additional sources of relevant data (including information held by community groups and their members. Organisations contacted included the following:

**Government Departments and Organisations**

- Conservation Commission of the Northern Territory;
- Department of Lands, Housing and Local Government;
- Aboriginal Areas Protection Authority;
- Darwin Port Authority;
- Fisheries Division of the Department of Primary Industry & Fisheries;
- Bureau of Meteorology;
- NT Museum;
- Department of Health & Community Services;
- CSIRO Division of Tropical Ecology;
- Northern Territory University.

**Commerce, Industry and Tourism**

- Northern Cement;
- Paspaley Pearling;
- Coral Divers; and
- Indo Pacific Marine.

**Community Groups**

- The Environment Centre NT Inc;
- National Trust of Australia (NT);
- Darwin Amateur Fishing Club;
- Amateur Fishing Consultative Committee
- SCUBA diving clubs; and
- Darwin Field Naturalists (including bird observers).
2. NEED FOR PROPOSAL

This section reviews the nature of the existing Port of Darwin, the present and projected demands on the port, and the port facilities and associated infrastructure which will be required to meet future needs.

2.1 EXISTING PORT FACILITIES

The existing port is situated adjacent to the Darwin CBD, immediately south of the Esplanade (Fig 2-1). The port area is located within 200m of the Administrator's residence and within 300m of State Square.

The port facilities consist of three discrete "pylon style" wharf structures comprising the Stokes Hill Wharf, the Fort Hill Wharf and the Iron Ore Wharf, together with a "roll on - roll off" facility located between the Iron Ore and Fort Hill wharves.

The present functions of these wharves are summarised below.

2.2.1 Stokes Hill Wharf
This wharf was constructed between 1953 and 1955 and is used for berthing passenger liners, trawlers, rig tenders, harbour ferries and other small craft. Refuelling facilities for naval and passenger vessels are available and often utilised.

The wharf is also used about every six months for unloading "clinker" for cement manufacture. This procedure involves depositing clinker directly onto the wharf surface using a grab, whereupon it is loaded into trucks by front end loader for transport to Northern Cement's Quarantine Island plant. The annual clinker import currently totals approximately 40 000 tonnes in two shipments.

Several permanent businesses and facilities exist on the wharf providing services in the tourism and hospitality industries. The businesses include a restaurant, takeaway food outlets, a cafe and souvenir shop. Under-cover market stalls on weekends and special occasions are established in an existing store shed. In addition, this wharf's features include a covered stage and walkway, an area designated for viewing performances from scaffold or open plan seating and provision for car parking adjacent to the stage and walkway.

The useful life expectancy of the Stokes Hill Wharf for current industrial port operations is estimated to be only about five years. Primarily, this is due to the condition of the structure and the extensive remedial works required to provide extra lateral stability for berthing larger ships. Maintenance works for this wharf are planned to be undertaken during the next few years.
2.1.2 Fort Hill Wharf

The Fort Hill Wharf was constructed between 1979 and 1984 and is used almost solely for industrial purposes, mainly involving the loading and unloading of vessels with cargo such as cattle, explosives, vehicles, general cargoes and containers for frozen meat and uranium in addition to servicing rig tenders. The existing facilities include a container crane, container storage area and vessel refuelling systems.

2.1.3 Iron Ore Wharf

This wharf, which was completed in 1967, is also used only for industrial purposes. It is equipped to store and load solid materials via conveyor and also to unload bulk fuel tankers.

The material currently loaded by conveyor is lead and zinc concentrate brought in from the Woodcutters Mine by road. Bulk fuel is currently unloaded from tankers and conveyed via pipelines to private storage facilities and Department Of Defence (Navy) storage tanks located at Stokes Hill and Frances Bay. The private storage facilities are operated by Shell, Mobil, Ampol and BP at Frances Bay, while a liquid petroleum gas (LPG) storage vessel operated by Boral is located in the northwest section of the wharf area (Fig 2.1).

2.1.4 Roll-On Roll-Off Facility

A "Ro/Ro" facility, which is capable of catering for any known Ro/Ro vessel configuration at all tide levels, was installed between the Fort Hill and Iron Ore wharves during 1982 and 1983.

2.1.5 Ancillary Facilities

Several other facilities exist in the area adjacent to the wharf front where the land (if not the structures) is owned by the NT Government and leased to private organisations. These include:

- a bitumen manufacturing plant;
- cement storage facilities;
- the LPG storage vessels;
- the conveyors and material storage sheds (currently used for lead and zinc concentrates);
- a (disused) iron ore stacker/reclaimer;
- two storage sheds, partially rented to private concerns; and
- a building located at the landward end of the Stokes Hill Wharf which houses displays of local marine ecosystems and cultured pearl production operated, respectively, by Indo Pacific Marine and the Australian Pearling Exhibition.
2.2 EXISTING AND POTENTIAL DEMANDS FOR PORT FACILITIES

The NT Government has long recognised the need to capitalise on Darwin's geographic location to promote trade with the Asia Pacific region. Increases in trade between Australia and Asia Pacific nations, particularly involving containerised cargo, have been predicted following overseas trade missions by both Federal and NT Governments. The recent appointment by the Federal Government of The Hon. Neville Wran ACOC to chair a committee to study the development of Darwin as a focus for developing Australia’s trade with East Asia is further clear evidence of Darwin's potential.

The NT Government has for many years argued for the completion of a rail link between Darwin and the southern and eastern states, in order to facilitate the movement of cargoes between our northern neighbours and Australia, via the Port of Darwin. Clearly, if this objective is to be realised, it will be necessary to develop an efficient port facility which is designed to incorporate a future rail link and is capable of expansion to meet future demands.

The East Arm port expansion is designed to be a top class and efficient facility able to be integrated with the proposed rail link. It's construction is seen as a major step towards constructing the full 'landbridge' link. Justification for the facility cannot, therefore be found in identified future demand which will depend critically on the proposed railway. For reference the Darwin Port Authority (DPA) has provided information on existing cargo volumes as tabulated in Table 2.1.

2.3 ABILITY OF CURRENT FACILITIES TO MEET EXISTING DEMANDS

Existing demands on the port are met by the current port facilities, with certain disadvantages that will be resolved by the new facility, these include: (1) the clinker unloading and transport operation places major demands on wharf space and available road transport and impacts on the urban road network; (2) the rate of container loading and unloading is limited by the available wharf area; and (3) the condition of the Stokes Hill Wharf structure will in due course result in a downrating and larger vessels will then use Fort Hill Wharf.

2.4 PORT FACILITIES REQUIRED TO MEET POTENTIAL DEMANDS

In order to meet the anticipated demands associated with construction of the rail to South Australia, provision needs to be made for the development of port facilities in Darwin possessing the following capacities and attributes:
- a modern, cost-competitive, port offering a fast turnaround for vessels and efficient transfer of cargoes to land transport systems and the Trade Development Zone.
- container berths totalling 900 m in length, capable of accommodating 60,000 dwt vessels;
- container crane(s) capable of lifting fully laden 40 foot containers to and from vessels with a beam of 32 m (the ISO rating for 40 foot containers is 40 t);
- container storage, and handling facilities with a capacity of up to 500,000 teu/annum;
- a railway cargo terminal, primarily for handling containerised freight;
- a "minor" bulk cargo berth complete with loading and unloading facilities, conveyors and storage buildings (capable of handling up to 2,000,000 t/y);
- a livestock loading and unloading berth capable of being used at all tide stages;
- berths for rig tenders and general shipping; complete with facilities for maintenance, bunkering, and taking on water and other supplies and equipment;
- adjacent on-shore areas suitable for a wide range of port-related activities and industries; and
- capacity to develop a major bulk handling facility including stockpile areas and rail loop.

The East Arm Port Expansion is designed to accommodate these requirements.
3. OPTIONS CONSIDERED

This section reviews the options which were considered by the NT Government in the process of arriving at its decisions to: (1) locate the new port at Quarantine Island in East Arm; (2) opt for a land-backed port configuration.

3.1 "NO ACTION" OPTION

The "no action" option would involve retaining the Port of Darwin at its existing location, and accepting the severe constraints inherent in such a situation. This option is incompatible with the Government’s plans to develop Darwin as a major trade centre serving the Asia Pacific region, as the present site cannot support a major port, nor is it likely that a satisfactory rail link through urbanised areas could be re-established to the existing port area.

The existing port facilities cannot achieve the cost-effectiveness expected of modern ports and the Stokes Hill Wharf has a limited lifespan for large vessel usage. While it would be possible to upgrade and/or replace the existing facilities to overcome their present shortcomings, the very substantial cost of such works could not be justified because the port could not be expanded to handle the projected future demands outlined earlier.

There are a number of important planning considerations which make any significant expansion of the existing port facilities inappropriate. These include:

- exacerbation of land use conflicts between the port and the adjoining city area;
- limitations on the ultimate area available for expansion;
- detraction from the amenity of the city area by increasing heavy vehicle movements associated with the port;
- adverse environmental effects associated with any plans to re-establish a rail link to the existing port; and
- the high value of the existing port area for redevelopment as a commercial, recreational and tourist precinct adjoining the central business district.

As outlined above, it is apparent that the present port location is not appropriate for expansion to support Darwin’s projected future port needs.

3.2 SITING OF NEW PORT

The main considerations in selecting the general location of a new port in Darwin are as follows:
• good access to deep water for vessels of up to 60 000 dwt (which draw approximately 15 m);
• good access for a future rail link from the south;
• ample room for development of a major port (including a major bulk facility should the need eventuate);
• good access to the Trade Development Zone, cement plant and existing industrial areas; and
• adequate separation from sensitive land uses such as residential areas.

Consideration of the siting requirements listed above leads to the conclusion that the options for siting a major new port in Darwin Harbour are extremely limited. Reference to Fig 3-1 indicates that Quarantine Island in East Arm is in fact the only location which meets these requirements, for the reasons outlined below:

• deep water channels in sheltered areas of the harbour are limited to East and Middle arms (refer to the 15 m depth contour);
• Quarantine Island and Channel Island are the only two locations where good road access is available to elevated ground in reasonable proximity to deep water;
• the area of potentially available land on Channel Island is extremely limited, as the (northern) section of the island not occupied by the power station is largely low-lying and possesses high environmental and heritage values (including numerous graves); and
• Channel Island is remote from the existing industrial areas and the Trade Development Zone, and future rail access to a new port on the island would require a long branch line involving bridges and causeways across extensive mangrove zones.

The above facts are entirely consistent with the Government’s August 1992 decision to develop a new port in East Arm, in the vicinity of Quarantine Island. Furthermore, discussions with representatives of a wide range of Government, commercial and community organisations in Darwin during preparation of this Draft EIS did not identify any significant disagreement with this decision, nor suggest any other potential alternative port sites.

3.3 EARLIER INVESTIGATIONS RELEVANT TO EAST ARM PORT

A number of geotechnical and hydrographic investigations have been undertaken over the past 25 years into the use of the section of East Arm near Quarantine Island as a port site, while additional relevant studies of this area have also been conducted in connection with a proposed power station and the management of wastewater discharges to the harbour. These investigations have included the following:
• Conceptual Design For Port Development, 1970 (Rendel and Partners);
• Darwin Offshore Supply Base Feasibility Study Report (Acer Vaughan / ADDCAP Consortium);
• Geotechnical Investigations, Proposed East Arm Trawler Facility, 1981 (Dames & Moore for NT Development Corporation);
• Fishing Harbour Master Plan, 1986 (Norgaard Aust. Pty Ltd); and
• Site Investigations For Second Power Station, 1973 and 1978 (Department Of Construction).

These reports, in conjunction with bathymetric data held by the DPA, provided the basis for preparation of the preliminary port layouts discussed in the following section.

3.4 NATURE OF PROPOSED EAST ARM PORT FACILITIES

The nature of the proposed East Arm port facilities is described in the recently released East Arm Port Development Masterplan prepared by GHD (Department of Transport and Works(1993)). The Master Plan includes conceptual plans and broad performance descriptions of the proposed facility up to it’s full development stage. Design details are not currently available and some of the decisions on matters such as preferred construction techniques (to cover such areas as dredging, placement of fill and armouring, and construction of berths) will only be confirmed when a successful contractor is in place. The various options for construction are therefore reviewed in this EIS.

3.4.1 Proposed Port Configuration

The broad concept for the proposed port, as shown in Fig 3-2, involves the construction of a land-backed port extending out from Quarantine Island towards the main East Arm channel (to the west of the Shell Islands). Dredging of a channel, swing basin and both deep water and shallow berths will provide fill for the project, as will rock and soil materials excavated from Quarantine Island. This design was selected by T&W as its preferred option following a review of a wide range of possible configurations involving various combinations of dredging, filling and piled structures.

The selected port concept was strongly influenced by advice from the DPA and the shipping industry to the effect that a fully landbacked design, complete with extensive onshore areas reserved for port-related activities, is essential if the new port is able to be cost-competitive with other modern ports. This design maximises accessibility between ship unloading cranes and the container storage area.
A further important consideration in the selection of the site and the design of the berths, turning basin and channel is the effect of the existing bathymetry and the port configuration on current speed and direction. The proposed concept seeks to optimise the orientation of the channel to achieve current flow as close as possible to parallel to its centre line, and to the berths.

The main elements of the "ultimate" port concept as depicted in Fig 3-3 are as follows:

**Container Terminal.** The 900 m long container berth complete with container cranes will be backed by a 42 ha container handling yard. This yard will be used for the storage of stacked containers, in readiness for loading on to shipping or land transport. The storage area is designed to be capable of providing rapid rolling stock and shipping turn around times to enhance efficiency. In general terms, sufficient space is to be made available to stockpile incoming and outgoing cargoes before and during loading/unloading of ships and trucks/trains. A customs building will be provided in this area, along with a dedicated area for any necessary fumigation and/or cleaning of containers.

**Rail Container Terminal and Rail Reserve.** A rail terminal designed for the efficient loading and unloading of containers will adjoin the northern edge of the container yard. A rail reserve will be located around the western shore of Quarantine Island to provide access to a future Berrimah rail freight terminal.

**General Port Area.** The general port area will include provisions for a heavy lift crane, and the loading and unloading of minor bulk cargoes (such as clinker), livestock and other general (non-containerised) cargoes. The general port area has an area of about 9 ha and will include a workshop and plant and facilities for the storing plant and equipment. The minor bulk berth has been sited to enable an overhead conveyor to be constructed, in future, on a direct line from the berth to Northern Cement’s existing clinker storage building.

**Port Administration Area.** This area will be located on the landward edge of the general port area and include the port offices, gatehouse, staff Amenities and parking.

**Future Port Usage Area.** This 58 ha area, comprising a 25 ha section of Quarantine Island and the remainder created by filling shallow areas of East Arm, are to be reserved for such uses as the berthing and maintenance of smaller commercial and fishing vessels (possibly involving a dry dock), a supply base for off-shore petroleum exploration and production, and other activities directly related to port activities.
Port-Related Industry. The remaining portion of Quarantine Island, totalling 35 ha and including the existing Northern Cement site, will be reserved for port-related industries.

Possible Future Major Bulk Cargo Facility. The area located between the proposed container port and the western shore of Quarantine Island will be reserved for a possible future major bulk facility, incorporating a 50 ha stockpile area surrounded by a rail loop. This area is not covered by the current EIS and would be included in environmental studies for the Alice Springs to Darwin railway.

Recreational Boating. A public boat ramp and vehicle and trailer parking area will be constructed to the north of Catalina Island to replace the existing facility on Quarantine Island.

3.5 STAGING OF DEVELOPMENT

The pattern of development of the new port will need to be flexible in order to respond to the growth in specific types of cargoes and port-related industries. Nonetheless the Masterplan document has established the conceptual framework for an on-going rational development of the new facilities as discussed below. The actual staging (except Stage 1) may differ markedly from this.

3.5.1 Stage 1
The initial stage will consist of 400m of deep water wharf frontage, dredging of a channel and turn-around basin, installation of a container crane (relocated from the existing Fort Hill Wharf) and the progressive infill of the area behind the wharf front and armoured bunds (Fig 3-4). A 6 ha (paved) hard stand storage area will be provided for containers, while unpaved areas will be available for temporary use for a range of port-related uses. Completion of Stage 1 will provide a general port facility to be used for handling containers, (bulk) cement clinker, live cattle and as a base for rig tenders and general shipping.

3.5.2 Stage 2
The second stage would be constructed as demand for facilities increases, possibly associated with the Darwin-Alice Springs rail link (Fig 3-5). It will include the installation of additional container cranes, extension of the (paved) hardstand area and construction of maintenance workshops, the railway around the eastern shore of Quarantine Island and a railway siding. These works will form the basis of Container Terminal No 1.
3.5.3 Stage 3
Stage 3 would involve a major extension of the container berth, land backing and rail siding to the west, over North Shell Island (Fig 3-6). The paved area will also be extended to the west to accommodate Container Terminal No 2, and additional container cranes added as required to cater for further increases in container traffic.

The dredged channel and basin will be extended to the south and east to facilitate the manoeuvring of larger vessels.

3.5.4 Stage 4
Stage 4 would essentially involve the completion of paving of the container port area and the installation of additional cranes and ancillary facilities to complete Container Terminal No 3 (Fig 3-7).

3.5.5 Alternative Development Programme (Stages A,B)
Figures 3-8 and 3-9 indicate how the staging of the port development could be managed beyond Stage 1 (above) in response to an accelerated demand for shallow berths and related on-shore facilities, for example, to service the oil and gas industry. In this case, development of the eastern section of the port might proceed before the addition of the second container terminal.
4. PROJECT DESCRIPTION

This section outlines the design of the proposed port, the proposed construction methods, the changed function of the existing Port of Darwin, and operation of the proposed port.

4.1 DESIGN OF PORT AND ASSOCIATED FACILITIES

The factors which were been taken into account in developing the design of the proposed port are outlined below.

4.1.1 Berths

The berths to be provided in stages 1 to 4 are as follows:

Stage 1. This stage will provide a 400 m long berth, with a berthing pocket dredged to -12.0 m Chart Datum (CD), suitable for vessels up to 40,000 dwt and a maximum length of 200 m.

Stage 2. This stage would extend the berth by 150m in length.

Stage 3. This stage would extend the berth by a further 150m.

Stage 4. A further 300m of berthage would be added to make a total of 900m.

4.1.2 Ship Support Facilities

Support facilities to be provided for vessels will include the following:

• diesel fuel and heavy oil supply for ship bunkering;
• potable water supply;
• garbage collection;
• electricity;
• sewage disposal facilities;
• telephone.
4.1.3 Urban Services Required

Power Supply

The site will be provided with electricity by connection to the existing Darwin supply system. This will be achieved by upgrading the existing distribution systems as follows:

- Stage 1 will require construction of new 11 kV overhead transmission line from the Berrimah Zone substation to the new port and installation of a substation and transformers at the termination of the feeder.
- Subsequent development would require construction of a 66/11 kV zone substation fed from the Hudson Creek substation.

Water Supply

This will be provided by augmenting the existing supply from the Trade Development Zone. A 19 ML storage site currently owned by the NT Government would be relocated to the site for storage.

Sewerage

Wastewater production at the site will be limited. It is currently envisaged that disposal to the requirements of the Power and Water Authority would be by septic tank with the treated effluent conveyed by a common pressurised main to soakage trenches, transpiration beds or a small pond system. Pumped disposal to the TDZ system would be installed when loads justify the investment. Temporary facilities will be required for handling sewage generated by the construction workforce.

4.1.4 Stormwater Drainage

The site will be drained to the harbour. Separator traps will be provided within the system to capture oil or fuel spillage.

4.1.5 Recreational and Educational Features

The shallow draught vessel servicing and maintenance area associated with the new port will include a new public boat ramp and associated parking areas. This will replace the existing Quarantine Island boat ramp which will be covered over during this phase of construction.
4.2 CONSTRUCTION PROCESS

4.2.1 Construction Methods - Port Reclamation Area

Construction of the main port area will involve the following steps:

1. construction of bunds using material excavated from Quarantine Island;
2. placement of armour rock on the outer faces of the bund using largely imported quarried materials from commercial quarries;
3. filling of the area within the bunds with a combination of dredge spoil and material from Quarantine Island; and
4. construction of the wharf front.

The precise construction methods to be used will not be determined until tenders have been evaluated; however, the general nature of these works is discussed below. These comments refer specifically to Stage 1 but are also relevant to subsequent stages.

Construction of Bunds

The proposed process for construction of the reclamation area involves, as a first step construction, to above the high tide mark, of a bund wall around the perimeter of the area to be reclaimed. The majority of the reclamation fill is then placed within the bunded area under controlled conditions not subject to the complications of tidal movements. The bund wall will be constructed of rockfill materials from the Quarantine Island earthworks. This material will be placed by end-tipping.

Placement of Armour Rock

As the bund wall progresses imported armour rock will be placed on the external face of the permanent faces of the bund wall to provide protection from wave attack.

Filling Within Bunded Area

Fill from the navigation dredging will be discharged into the bunded area to create the main reclamation. A topping layer to form foundations for a hardstand will then be constructed from material excavated from Quarantine Island. The level of the hardstand is currently proposed to be 9.5m AHD. This will be confirmed after assessment of storm surge analysis results currently being reported (Acer Vaughan/Vipac (1993))
Construction of Wharf Front

The Stage 1 wharf frontage on the southern face of the reclamation is likely to be constructed using one of the following techniques:

- **Solid Faced Wharf** constructed of pre-cast hollow box units, cast on site and lifted into position by crane. The units would be installed on a prepared crushed rock foundation, would be filled with sand after installation and would be capped with insitu concrete.

- **Open Faced Suspended Deck Wharf** similar in construction to the existing Fort Hill Wharf. This would be supported on tubular steel piles driven into the seabed. A reinforced concrete wharf deck would then be formed on top of the piles.

- **Roller Compacted Concrete Wharf.** Unlike the other two options, which would be constructed in front of the reclamation bund wall, this option would be constructed behind a further, temporary, bund wall in dry conditions. The roller compacted concrete wharf would then be placed in layers on a prepared foundation to produce a vertical faced gravity retaining wall. The temporary bund wall would then be removed and used in the general reclamation.

4.2.2 Dredging

Dredging of the channel and swing basin will be undertaken using a cutter-suction dredge, and all dredge spoil will be deposited within the bunds forming the perimeter of the development as described above. A decant arrangement will apply in the reclamation area to separate the dredged fill and water. The dredge water will be returned to the harbour. The extent of dredging has been co-ordinated with the need for fill during the staged construction of the port. The initial dredging will consist simply of the channel and swing basin associated with the first container berth.

4.2.3 Sources and Quantities of Fill

The armour rock to be placed on the north, west and east sides of the proposed port will largely consist of rock imported from commercial quarries but some may be won from the Quarantine Island earthworks. Material dredged from the navigational channel, swing basin and berthing pocket will be deposited inside the bunds to form a base upon which a hardstand area will be constructed using material excavated from Quarantine Island. However, as indicated below, there will be an estimated shortfall of approximately 1.25 million cubic metres of fill material for the ultimate development and the source of this fill will have to be determined at
Figure 3-10 indicates the expected sources of fill and dredge spoil for Stages 1 to 4, while the sources and volumes of fill material required for each stage, excluding armour rock, are discussed below.

Stage 1 (refer to Fig 3-4)

- The total amount of fill material required for Stage 1 is estimated to be 3.6 million cubic metres.
- The volume of dredged material from the swing basin and channel is 2.5 million cubic metres.
- The total volume of material to be excavated from Quarantine Island for Stage 1 will be 1.1 million cubic metres, of which 0.45 million cubic metres will be used for construction of the bund walls.

Therefore, all fill required for Stage 1 will be obtained from Quarantine Island or the navigational dredging requirements.

Stage 2 (refer to Fig 3-5)

- The total additional amount of fill material required for Stage 2 is estimated to be of the order 1.1 million cubic metres.
- 0.2 million cubic metres of this material would be excavated from Quarantine Island.
- 0.9 million cubic metres would either be obtained by advancing Stage 3 dredging or by importing from off-site.

Stage 3 (refer to Fig 3-6)

- The total amount of additional fill material required for Stage 3 is estimated to be 2.4 million cubic metres of which 0.45 million is select fill; the rest will be obtained from dredge spoil.
- The volume of dredged material from the swing basin and channel is anticipated to be of the order 2.8 million cubic metres, a surplus of 0.85 million cubic metres. This would be used either in Stage 2 by advancing some of the dredging or to pre-construct part of a subsequent stage.
- 0.15 million cubic metres of select fill would be imported from off-site and 0.3 million would be obtained from Quarantine Island.

Stage 4 (refer to Fig 3-7)

- The total amount of additional fill required for Stage 4 is estimated to be 0.15 million cubic metres of selected fill to raise reclamation areas from Stage 3.
This material would be imported from off-site.

Stages A, B and beyond (Figures 3-8 and 3-9)

- A further 2.4 million cubic metres of fill of which 0.6 million is selected fill is required to complete the project covered by this EIS.
- 1.8 million cubic metres of material would become available from the additional navigation dredging required (0.3 brought forward from Stage 3).
- 0.9 million cubic metres would be imported from off-site.

Ultimate Development (Figure 1-3)

- The total amount of fill material required is estimated to be 9.65 million cubic metres.
- The volume of dredged material from the swing basin and channels is of the order 6.8 million cubic metres.
- The total volume of material available from Quarantine Island is estimated to be 1.6 million cubic metres.

It is apparent from the above figures that there will be a shortfall of approximately 1.25 million cubic metres of fill for the ultimate development. The source of the material to be used in this aspect of construction has not been specified and therefore cannot be examined by this EIS. A separate environmental assessment may be necessary to define the effects of this operation if and when these works are to be undertaken.

4.2.4 Extraction, Transport and Placement of Fill

It is possible that some blasting will be used to facilitate the Quarantine Island earthworks. A combination of machinery consisting of scrapers and trucks will then be used to remove the material and transport it to the site. Sprayed water will be used as necessary to minimise dust problems on haul roads within the site.

Construction of the Stage 1 bund walls (requiring some 0.45 million cubic metres of material) is expected to take approximately six months to complete.

4.2.5 Construction of Associated Transportation Infrastructure

The existing access road to the site will be upgraded in conjunction with the Stage 1 construction, with the proposed roadworks following the existing alignment. The ultimate development will also include an additional road on Quarantine Island to enable access to the shallow draught vessel service and maintenance area and boat ramp at the eastern end of the port (Figure 3.3).
It is anticipated that construction of a railway link to the port from South Australia might form the trigger for Stage 2 construction (Figure 3.5). This would involve the construction of a railway embankment around the west shore of Quarantine Island. A separate EIS will be required for this as part of the main Darwin to Alice Springs railway construction project.

4.2.6 Construction Schedule

Current expectations are that the first contract in the Stage 1 construction which will be the bund and access earthworks will commence in late February 1994. Further contracts would then be let for Dredging and Wharf Construction and a total Stage 1 construction period of 24 months is envisaged.

No time frame can be established currently for succeeding stages of the project. These will respond naturally to the ongoing development of Darwin as a focus for Australian trade with Asia.

4.2.7 Construction Workforce

The site works are not highly labour intensive and a modest workforce only is anticipated at this stage. The workforce is unlikely to exceed 50 persons at any given time and this will not put any strain on local facilities and is likely to be locally sourced generally.

4.2.8 Management of Construction Wastes

All run-off water from the site during construction phases will be directed through settling ponds primarily constructed for the settling of spoil material obtained in dredging operations.

Solid wastes generated during the construction phases will be disposed of to approved landfill sites.

4.3 REVISED FUNCTION OF CURRENT PORT FACILITIES

4.3.1 Programme

The relocation of the existing container crane from the Fort Hill wharf to the new port before the commissioning of Stage 1 will mean the transfer of all container traffic to the East Arm port. Other activities to be transferred to the new port at the completion of Stage 1 are the handling of livestock and cement clinker. However, it is not planned to relocate the existing bitumen plant, cement silos or lead and zinc loading facilities or functions at the initial stage of the new port.
The existing "roll on / roll off" facility will also be retained at its current location in the short term at least.

4.3.2 Potential for Re-Use of Port Facilities

As noted above, the only major facility to be relocated from the existing to the new port is the container crane. However, smaller items such as forklift trucks will be transferred along with the container operations.

4.3.3 Future Uses of Land

Further development of the port precinct recreational and tourist features will occur following the progressive transfer of port functions from the existing port site. These developments are currently in the preliminary planning stages but plans include construction of a swimming area, grassed areas, food outlets and walkways.

4.4 OPERATION OF PROPOSED PORT

This section discusses the operation of the proposed facilities associated with the new port facilities at East Arm.

4.4.1 Shipping Movements

As the proposed location of the port is within Darwin Harbour and a channel will be dredged to enable access to the berthing area then it follows that all major shipping traffic will be confined to within the natural and dredged channels. These channels will be marked with navigation beacons to enable safe navigation between the new port and channels currently used in the operation of the existing port.

Berthing and unberthing manoeuvres will need to take account of eddies and tidal currents in the channel and swing basin, which are predicted to reach 4.0 knots (1.8 m/s) during spring tides (refer to Section 5.3). In comparison, the maximum current velocity in the vicinity of the existing port is 3.0 knots (Ref: The Port of Darwin Handbook).

The existing port operation involves the use of one tug boat and the services of two pilots. The need for more pilots is not envisaged for Stage 1 of the project; however, a second tug will be required in due course for the berthing of large vessels at the new port. This would be a natural progression as the number and size of vessels visiting the port increases.
4.4.2 Types of Cargo

Many of the existing activities of the current Port of Darwin will be transferred to East Arm. Initially this would include:

- container handling operations;
- live cattle export;
- general cargoes;
- bulk cargoes (import);
- offshore oil supply tenders.

In the future it is anticipated that bulk export cargoes would also be handled through the East Arm facility and for this purpose a bulk berth capable of handling 2 million tonnes/annum has been provided for.

4.4.3 Loading and Unloading of Vessels

The loading and unloading of vessels in Stage 1 will involve the relocated Fort Hill container crane, which will transfer containers directly between vessels and trailers. These trailers will then be towed by tractor to the container storage area. No other unloading apparatus such as bulk loaders/unloaders or conveyors are planned for the initial stage of the project. However, the proposed design makes allowance for future developments such as additional container cranes and bulk materials handling equipment.

4.4.4 Cargo Storage and Handling

Containers awaiting loading onto and those unloaded from vessels will be stored in the hardstand area between the berthing site and the proposed railway terminus. Containers are expected to be stacked in this area by rubber tyred gantry cranes. Transport of containers to and from the storage area is to be carried out by use of a tractor/trailer combination. These will be loaded and unloaded by rubber tyred gantry (RTG) at the container storage area and by rail mounted gantry (RMG) at the railway sidings when constructed. In the early stages of the project and prior to construction of the railway, road trains will be loaded and unloaded by the existing container crane relocated from Fort Hill Wharf.

A dedicated area will be provided for the cleaning and fumigation of containers when required to meet quarantine requirements.

4.4.5 Land Transportation

Stage one of the development does not include construction of a rail link to South
Australia. Therefore, all cargo will be transported to and from the new port by road transport.

4.4.6 Workforce

With the transfer of many of the existing functions of the port to East Arm it is anticipated that in the short term the workforce will not differ significantly from that which would anyway eventuate at the current facility when waterfront reform initiatives are completed.

4.4.7 Maintenance Dredging

It is envisaged that regular maintenance dredging will be required, at least during the early years of the port, to remove sand and gravel which will tend to be deposited in the dredged areas from the surrounding channel deposits. Spoil material arising from maintenance dredging will provide good quality fill for progressive construction of the hardstand areas of the new port.

4.4.8 Waste Management

Waste management at the proposed facility will comprise the following:

**Combustible Wastes** will be removed from site and incinerated or disposed of at the municipal tip.

**Waste Lubricating Oil, Bilge Oil** will be removed from site by contractor.

**Contaminant Risk Areas** such as workshops, fuel storage areas will be provided with separator traps to trap spillage.

4.4.9 Contingency Plans for Emergencies

The emergency procedures as set out for the existing port will also apply to the East Arm facility and consist of four components administered by three separate organisations. The procedures are segregated to cater for four specific forms of potential hazard:

- cyclone emergency;
- potential incidents involving tankers and dangerous goods;
- nuclear powered vessels; and
- oil pollution and spills.

The DPA is responsible for procedures related to cyclone emergency and incidents involving tankers and dangerous goods, whilst Emergency Services and the Marine
Division of Transport And Works are responsible for procedures associated with the presence of nuclear powered vessels and with oil pollution matters, respectively.

In relation to Oil Spill Containment and Recovery Facilities the DPA, the Navy, BP and Mobil have equipment and supplies on hand in Darwin to deal with any oil spills. If necessary, additional equipment and supplies can also be obtained from other port authorities at short notice under the "National Plan to Combat Pollution of the Sea By Oil".

DPA has advised that equipment and supplies presently available in Darwin or on order under the "National Plan" include the following:

- 360 m oil boom
- oil skimmer
- 250 m long absorbent booms
- large stock of absorbent pads
- 10,500 L third generation dispersant
- 20,000 L first generation dispersant

In addition, DPA has ordered the following items for delivery in 1993/94 to supplement the "National Plan" stockpile:

- 1,150 m oil boom
- helicopter spray bucket for dispersant
5. EXISTING CONDITIONS AND ENVIRONMENTAL EFFECTS

This chapter describes existing conditions and assesses the potential environmental effects of the proposal. Environmental safeguards designed to minimise the identified impacts and a recommended monitoring programme are described in Chapter 6.

As noted earlier, an environmental assessment of the East Arm Port zone was prepared in 1990 in connection with the proposed ADDCAP offshore supply base proposal. The assessment, which is described in Volume II of the ADDCAP report, included descriptions of existing environmental conditions within the present study area, based on both field investigations and an analysis of available data (Acer Vaughan 1990a). The ADDCAP reports are the property of the NT Government, and therefore the information contained in them is available for use in this EIS.

When the scope of this EIS was finalised in discussions with T&W, it was recognised that: (1) there was no need to repeat work already carried out as part of the ADDCAP study; and (2) additional field investigations would only be required in some specific areas (mainly involving currents, sediment behaviour and marine biota in East Arm). The descriptions in the ADDCAP report of most other sectors of the environment were considered to be adequate by the NT Government Departments involved in the review of the report. Thus, the approach adopted during preparation of the “existing conditions” sections of this EIS has been to: (1) draw information directly from the ADDCAP report where considered appropriate; (2) update this information as required; and (3) supplement it with the results of the additional investigations which were carried out as part of this EIS.

Text in this chapter which is transcribed directly from Volume II of the ADDCAP report (Acer Vaughan 1990a) appears in italics.

5.1 TERRESTRIAL ENVIRONMENT

The terrestrial environment includes those parts of the study area which are above the high tide mark (ie above about 3.9 m AHD). For convenience, all avifauna (birds) are discussed below (including species which are most commonly observed in the estuary).

5.1.1 Existing Conditions

Climate

The monsoonal climate of Darwin is characterised by a hot, humid, wet season (typically from November to March) a hot, dry season (typically from May to
September) separated by relatively short transitional periods (typically April and October).

The mean annual rainfall of 1,659 mm is highly seasonal, varying from an average of 1 mm in July to 404 mm in January. Rainfall was recorded on Quarantine Island between 1934 and 1985, with an annual mean value of 1,551 mm. Relative humidity at 9 am varies from a low of 62 per cent in June to a maximum of 84 per cent in February, with respective monthly values of 38 to 71 per cent at 3 pm. High precipitation rates are commonly experienced during storm events in the wet season.

Temperatures tend to remain within a relatively narrow range throughout the year, with mean daily minima varying from 19.2 (July) to 25.2 (November) and mean daily maxima for the same months varying from 30.3 (July) to 33.1 (Nov) (all in degrees Celsius).

Winds

During the dry season synoptic winds tend to be dominated by the south-east trade winds, while light west to northwesterlies predominate during the wet season. Seabreezes from the northwest occur on most afternoons throughout the year. An analysis of (non-cyclonic) 10-minute averaged winds is included in the January 1993 "Scope Report" prepared by GHD for T&W. These data, which provide the basis for predicting wave heights and assessing the influence of wind on vessels during berthing and unberthing manoeuvres, indicate that the strongest (non-cyclonic) winds blow from the westerly quarter, reaching velocities of 15, 26 and 55 km/h for average return periods of one week, one month and one year, respectively.

Cyclones

Tropical cyclones occur in the Darwin region on average about once per year. Australian Standard AS 1170 Part 2-1989 specifies likely maximum gusts during cyclonic events in Darwin for purposes of structural designs. The standard indicates likely maximum gusts of 180, 205 and 252 km/h for cyclones having mean return periods of 20, 100 and 1,000 years, respectively.

Landforms, Geology and Soils

Quarantine Island comprises two major land systems: the Bustard and Littoral systems (Fogarty et al. 1979) (Fig 5-1).

Quarantine Island has formed where hills of the original terrain have been isolated by marine flooding and tidal deposits since Quaternary times (Seminiuk 1985). The
small offshore islands, North and South Shell, Old Man Rock and Catalina Island are formed of more resistant lithologies and are surrounded by chenier ridges, sand spits and reefs as a result of tide and wave action.

The Bustard land system forms the hinterland and hinterland margin of Quarantine Island, and is characterised by rolling hills forming a low plateau, rising to 24 m AHD. The slopes are gentle (2-5%) and relief is up to 10 m. On the lower slopes a laterite profile has been formed while on the upper slopes the soils are lithosols. These lithosols have a high content of gravel (40-70%) and are shallow with sandy textures, resulting in excessive drainage. These characteristics place severe limitations for urban or intensive agricultural use (Fogarty et al. 1979).

The geology of this land system is primarily the Burrell Creek Formation, an early proterozoic sedimentary unit (Pietsch 1983). The lithologies range from fine-grained siltstones and sandstones to coarser quartz conglomerates. From field observations along a road cutting, the rocks display considerable variation in hardness, texture and weathering. Further investigation will be required before this rock is used as a construction material.

The Littoral land system forms a fringe around Quarantine Island and is dominated by the mangrove community (Fig 5-1). At the southern end of the island the mangrove fringe is narrow due to a rockier coast.

Topographically the Littoral land system has negligible relief and slope, and is inundated by seawater at peak high tides. The mangroves grow in a substrate of mud (clay minerals and quartz silt) formed by sedimentary progradation, in a broad zone up to 750m wide (Semeniuk 1985). Large areas of salt flats occur on the western edge of Quarantine Island as a result of hypersaline groundwater (Semeniuk 1985).

The margin of the hinterland forms an apron of colluvium/sheetwash that is infrequently inundated by seawater (Semeniuk 1985). The offshore islands are formed of resistant Burrell Creek Formation sandstones and conglomerates (Pietsch 1983). Marine processes such as wave action and tidal sedimentation have produced a number of features including chenier ridges and shell banks, sand spits, ripples, and large mud banks adjoining North Shell and Catalina Islands and Quarantine Island at low tide. Coral reefs are found surrounding North and South Shell Islands.

Hydrology

Quarantine Island is dominated by a north-south trending ridge which controls runoff. Due to the small catchment area well-developed drainage channels are not present. Runoff is via overland flow with seepage occurring through the porous
soil to prevent ponding. There are no known reserves of groundwater present on the island (Hollingsworth 1982).

Flora

The terrestrial plant associations are described below.

**Paperbark Forest.** The landward fringe of the intertidal zone is frequently an area where seepage from the hinterland occurs. This habitat is characterised by paperbark forest dominated by *Melaleuca leucadendron* or *Melaleuca viridiflora*. The paperbark community varies in extent from a zone 60m in width to a band only a few trees wide. The forest structure is typically parklike with an absence of understorey species and is largely monospecific. To the north of the development site the paperbark forests show some signs of disturbance (e.g. fire, clearing etc) and *Acacia auriculiformis* and *Acacia holosericea* are common upper and mid-stratum species respectively.

**Littoral Woodland.** Immediately adjacent to the landward extreme of the mangroves is a diverse plant community both in numbers of species (see Appendix A) and types of habitats.

The existing plant assemblage in the Littoral Woodland Zone varies largely according to the substrate type and the degree of disturbance. Much of this woodland has previously been removed or partially cleared for earlier developments in addition to cyclone damage incurred in 1974. Littoral Woodland includes:

- **The vegetation of low lateritic cliffs and stabilised dunes above the beach of mangrove:** a narrow sandy beach often separates intertidal and hinterland habitats - particularly to landward of the Rocky Shore Zone (Fig 5-2). Here, the three common dominant species are *Hibiscus tiliaceus*, *Thespesia populnea* and *Dodonaea platyptera*.

- **Coastal monsoon vine-thicket:** situated directly behind the mangroves or beach, a sparse, rather depauperate coastal monsoon vine-thicket occurs. Vine-thicket is found sporadically around the East Arm headland, varying in extent from a band a few metres in width on the south eastern side of the Island to a dense thicket over 50m wide on the northern side of the Island.

Certain thicket species are abundant in this community, becoming locally dominant or forming dense stands. Sections of coastal vine-thicket to the north are dominated by *Stenocarpus cunninhamii* or *Dodonaea platyptera*. Elsewhere stands of *Carthormion umbellatum*, *Acacia auriculiformis*, or *Melaleuca leucadendron* dominate the thicket community. Common vines
include *Flagellaria indica*, *Cassytha filiformis*, *Capparis sepiaria* and *Seccamone elliptica*.

- The adjacent woodland community which contains a high proportion of vine-thicket species: on rocky slopes and ledges above the mangroves *Eucalyptus tectifica*, *Acacia auriculiformis*, or *Melaleuca leucadendron* are the dominant species in a woodland assemblage.

  The mid-stratum is often dominated by *Acacia aulacocarpa* and the coloniser *Acacia holosericea*. A dense layer of seasonal grasses (eg. *Sorghum* sp. and *Pennisetum polystachion*) is indicative of the level of disturbance.

  Other species occurring in Littoral Woodland include *Vitex glabrata*, *Sterculia quadrifida*, *Antidesma ghaesemblia*, *Flagellaria indica* and *Trema tomentosa*. These species are commonly associated with coastal vine-thicket but here occur interspersed with woodland vegetation.

**Woodland.** Eucalypt-dominated woodland is the most extensive hinterland vegetation community. *Eucalyptus bleeseri* is the dominant species on the rocky, steeply inclined slopes with *Eucalyptus miniata* (Darwin woolly-butt) and *Eucalyptus tetrodonta* (Darwin stringybark) becoming the dominant species on more undulating ground.

  Common secondary trees in the woodland include *Acacia aulacocarpa*, *Buchanania obovata*, *Ficus opposita*, *Erythrophleum chlorostachys* and *Brachychiton diversifolium*. Also common throughout the woodland are tree species frequently found in monsoon vine-forest associations including *Canarium australianum*, *Drypetes lasiogyna*, *Alstonia actinophylla*, *Eleacarpus arnhemicus*, *Denhamia obscura* and *Strychnos lucida*.

  The low shrubs *Petalostigma quadriloculare*, *Jasminum molle* and *Flueggia virosa* occur amongst a dense grass layer dominated by *Sorghum* sp. and *Pennisetum* spp. Appendix A lists the Woodland plant species recorded during the site survey.

**Vine-Thicket.** In addition to the typically narrow band of coastal monsoon vine-thicket found within the Littoral Woodland Zone (lying directly behind the mangroves) are discontinuous patches of vine-thicket interspersed with eucalypt woodland around the slopes of the hinterland. These vine-thickets have a different character (summarised in Appendix C) and are thus considered separately.

  The dominant tree species in hinterland thickets usually include: *Pouteria sericea*, *Vitex glabrata*, *Strychnos lucida*, *Denhamia obscura*, *Sterculia quadrifida* and *Drypetes lasiogyna*. The most common mid-stratum species are *Eleacarpus arnhemicus*, *Memecylon pauciflorum*, *Antidesma ghaesemblia*, *Diospyros compacta*...
and Glochidion Xerocarpum. Vine species are abundant and characteristic of this community. Smilax australis, Flagelleria indica, Cassytha filiformis, Discorea transversa and Gymnema germinatum frequently entwine the vegetation impeding access through these thickets.

**Mixed Woodland.** The mixed woodland community comprises variable vegetation on a variety of substrate types to the north and north east of the proposed development area (Fig 5.2). The dominant species are largely hardy opportunists colonising areas in various stages of regeneration (Appendix A). Tall thickets of Calytrix brownii are common on exposed or rocky ground and dense thickets of Acacia holosericea and Acacia torulosa are characteristic of mixed woodland. Scattered Cypress Pine (Callitris intratropica) occur along the road verges and behind the mangroves with associated species including Grevillea decurrens and Wrightia saligna.

On low-lying or poorly drained areas Melaleuca viridiflora and Pandanus spiralis form the dominant species in an open woodland with Xanthostemon paradoxus becoming more common to the periphery of seasonally damp areas.

To the north east of the site on the far side of the mangrove inlet, common understorey species include Hakea arboriscens, Cochlospermum fraseri, Grevillea decurrens and Livistona humilis.

**Open Woodland.** The areas described as open woodland are largely a modified woodland due to partial or complete clearing of the native species in open woodland. The two former species represent remnant individuals, whilst the latter were probably planted.

**Terrestrial Vegetation of the East Arm Islands.** Fig 5-4 shows the distribution of the plant communities found on the three islands of the East Arm Peninsula region.

- **Catalina Island.** This rock-based island lies very close to the mainland, and of the three islands it has the largest area of hinterland vegetation - the rocky spine of the island extending several metres above the high tide mark.

  The Littoral Woodland community is comprised largely of coastal vine thicket species (Appendix A) with some open areas colonised by introduced vine species including Merrima aegyptia and Passiflora foetida.

- **North Shell Island.** All vegetation on North Shell Island occurring above the intertidal zone is found on a narrow, compacted sand and shell ridge. This interesting community is dominated by three species; Premna serratifolia, (a spreading shrub to 3m tall), stunted Sterculia quadrifida (to 3m) and Dodonaea platyptera (to 4m). Two vine species were also recorded -
Ipomea macrantha and Ipomea pes-caprae.

- **South Shell Island.** No terrestrial plants are present on South Shell Island because it is completely inundated during peak tides.

**Terrestrial Fauna**

The wildlife on the proposed Supply Base dry land areas is representative of the coastal Top End. Examination of the CCNT Coastal Resources Atlas, and the Recreation and Conservation Priorities Register indicated that no terrestrial sites of special faunal significance are known to occur on Quarantine Island.

A field survey was conducted on 14 June 1990 and again on 20-21 June 1990. The Quarantine Island area of the proposed land-based development, and the Shell Islands were searched for the presence of birds, mammals and reptiles, including direct observations, tracks and traces. One hundred small mammal "Elliot" traps were set for one night (20/6/90) covering three habitats: mangrove margins; open forest; and vine thickets.

**Birds.** During field trips a total of 56 species of birds were recorded (Appendix D). Of these about 90% were resident species. The remainder included nomads (Varied Tiller and Figbird) and migrants (four wader species). The number of waders recorded was very low as these are migrants which frequent northern Australia during the wet season (August-February). One species with a restricted distribution was recorded, the Mangrove Golden Whistler. This is a mangrove specialist confined to the northern Australian coastline, but occurring in disjunct populations of apparently low densities.

A quantity of guano marked a roost site in a patch of Sonneratia alba on North Shell Island which is frequented by Reef Herons and Large Egrets. North and South Shell Islands were also inhabited by a pair of Beach Thick-knees and Pied Oystercatchers.

There are 91 bird species found commonly in the seven habitats of the Darwin region (Thompson and Goodfellow 1987). All species of bird recorded in the Supply Base Area are well represented elsewhere in the Darwin/Bynoe Harbour marine and terrestrial areas.

North and South Shell Islands and Old Man Rock are considered significant high tide roosts for migratory waders (CCNT Coastal Resources Atlas). Up to 4000 birds, including the Terek Sandpiper Xenus cinereus which occurs in low numbers worldwide, have been recorded in these roosts during wet season wader migrations. These sites are noted as excellent bird habitat in McKean and Martin (1986).
Discussions with local bird observers indicate that little detailed information is available on birds on the Shell Islands, largely because they have been relatively inaccessible to bird observers (A Hertog, H Thompson, N McCrie, pers comm). Hence a brief investigation was undertaken by H Thompson, as part of the EIS studies, to survey the bird life on North Shell Island and to assess the importance of North Shell Island as a resting area for wading birds. A report on the investigation is presented in Appendix J. A total of thirteen species and an average of 98 birds were observed in two, 2-hour, high tide surveys of North Shell Island.

The survey and the general consensus of local ornithologists indicate that the Shell Islands now represent an interesting, but relatively minor, high tide roosting area for birds (including migratory waders), and that much larger numbers of bird roost in areas around Shoal Bay, including Lee Point, Tree Point and sand bars in the vicinity of Buffalo Creek and the Howard River. It has been suggested that the number of birds roosting on North Shell Island has substantially decreased in recent years because of increased levels of human (and dog) visitation as a result of improvements to the Quarantine Island boat ramp and access road (Hertog, pers comm). Trees on Catalina Island are used for roosting by large numbers of birds, including Reef Herons and Kites (Hertog, pers comm). Overall, therefore, North Shell Island is considered of insignificant value as a roosting site for waders.

Nevertheless, the use of North Shell Island as a roost by vulnerable species such as the Terek Sandpiper, Little Tern and Beach Thick-knee make it a significant habitat for these birds, and monitoring is recommended.

Trees on Catalina Island are used for roosting by large numbers of birds, including Reef Herons and Kites (Hertog, pers comm).

**Mammals.** Eight species of mammal were observed in the area (Appendix D). Small mammal traps captured two species, Grassland Melomys and Northern Brown Bandicoot. Both of these species were captured along the mangrove fringe where it was bordered by dense grass. Northern Brown Bandicoot and Feral Pig diggings were also observed in this location.

In the woodland and vine-thickets, droppings and tracks of Northern Brushtail Possum and Northern Quoll were common. The most obvious mammal in the area was the Agile Wallaby. This species occurs in large numbers on Quarantine Island and adjacent areas of the East Arm Peninsula. A pair of Antilopine Kangaroos was also observed.

Most of the species observed are typical of those which occur in disturbed and semi-urbanised areas around Darwin. O'Gower (1979) found that species such as the Northern Brushtail Possum, Northern Brown Bandicoot, Grassland Melomys and Water Rat (Hydromys chrysogaster) were particularly common in mangrove
margin habitats in the Darwin area. Only the latter species was not recorded on Quarantine Island (Appendix E) although it may be present.

It is likely that many other mammal species occur in the area. Many of the 26 species noted from the Darwin area by O'Gower (1979) could occur on the site. The only rare or endangered mammal species known from the Darwin area is the Ghost Bat (Macroderma gigas) (McKean 1979). No suitable roosting sites for this species occur on the project area.

**Reptiles.** Seven terrestrial reptile species were observed at the site (Appendix E). All of the species observed are generally common in the Darwin area. A number of additional species could be expected. Along the mangrove fringes, three species of Carlia skink were common. In this area, there was a lot of dumped rubbish, particularly sheet iron, which provides cover for terrestrial reptiles. The Prickly Gecko was common in this area.

There is no fresh water at the site, although a small stream may flow through the area during the wet season. There are probably few amphibians on the site, although the Green Tree Frog (Litoria Caerulea) is likely to be present.

None of the 40 species of terrestrial reptiles listed by O'Gower (1979) from the Darwin area are regarded as rare or restricted in distribution.

No evidence of terrestrial reptiles or mammals was found on either of the Shell Islands.

**Biting Insects.** Biting insects are an important consideration in developments for human occupation in the Top End as, in addition to creating a nuisance, they can present a public health problem through transmission of diseases. Biting insects of the Northern Territory include mosquitoes and midges, with march flies occurring to a lesser extent. Ninety-five species of mosquito have been identified in the Northern Territory with 65 species collected in the Darwin area and 61 species from Palmerston (Liehne 1985). Of these, 15 are considered as serious pests or vectors of disease. They breed in the intertidal mangrove zone and low-lying zone between mangroves and terrestrial open forest from 3.3 m AHD to 1.0 m above maximum high tide at various times of the year (Whelan 1988).

Thirty-three species of biting midge (Culicoides) have been recorded in the Darwin area (Liehne 1985). These species are not known to carry diseases of man, but are vectors of a number of serious virus and parasitic diseases of domestic stock. The major pest species to man is Clornatus, which breeds in the mangrove zone. Other biting insects recorded in this area include the march flies (Tabanidae). They do not transmit any human diseases but are vectors of some parasitic diseases of stock.
Quarantine Island has a high density of biting midges; however, there are no large mosquito breeding sites in the immediate vicinity. High numbers of biting midges occur in the upper reaches of Bleezers and Hudson creeks, and cause serious human discomfort in Berrimah and Hidden Valley Speedway. Biting Midge are also a perennial problem at the cement plant on Quarantine Island. Minor mosquito breeding areas have been identified near the Trade Development Zone and East Arm Leprosarium (P Whelan, Pers Comm).

5.1.2 Environmental Effects

This section reviews the environmental effects of the construction and operation of the proposed port on the terrestrial environment.

Construction Phase

Construction of the proposed port and associated port-related industrial area, as depicted in the Master Plan, will result in the progressive removal of elevated sections of Quarantine Island to create a relatively flat landform which is suitable for industrial use and provides fill for the port. This will require the progressive removal of essentially all of the existing terrestrial vegetation and faunal habitats.

The removal of vegetation, coupled with the disturbance associated with extraction of construction material, will greatly increase the potential for erosion of this area during the wet season, leading to increased sediment loads on adjoining sections of East Arm. However, the adoption of good construction practices (including minimising the extent of disturbed areas as far as possible, re-establishing ground cover as soon as possible, and where appropriate providing silt traps and temporary drainage works to direct runoff away from susceptible areas before the onset of the wet season) can greatly minimise erosion and resultant sediment discharges. Care will have to be taken in the design of drainage works to avoid creating significant breeding areas for mosquitoes.

The impact of the loss of terrestrial vegetation (and hence faunal habitat) from Quarantine Island is considered to be relatively insignificant, as the plant communities have been extensively disturbed in the past and anyhow are well represented in the Top End. Most of the vegetation to be affected consists of a eucalypt-dominated woodland, which is very widespread in the Darwin region. However, as indicated on Fig 5-2, several small remnant patches of monsoon vine thicket are also present on Quarantine Island. These vine thickets have a more diverse flora than the woodland areas, but as noted earlier, were not found to contain any rare or threatened species. The distribution and extent of monsoon vine thicket vegetation in the region is believed to have been progressively decreasing since European settlement, largely as a result of more frequent fires.
Therefore, the long-term outlook for the remnant vine thicket patches on Quarantine Island would be uncertain at best, even in the absence of the port proposal.

The proposal will ultimately lead to the loss of virtually all of the existing terrestrial habitat for native fauna on Quarantine Island. This habitat has been significantly disturbed by human activity and does not appear to support any rare or endangered species. Fauna will be progressively displaced from Quarantine Island into surrounding areas as the port and associated industrial areas are developed. However, this is not considered to represent a significant regional impact because Quarantine Island provides only a very small proportion of the existing habitat areas around Darwin Harbour.

The port will ultimately be extended to cover North Shell Island, at which time the latter will cease to be available as a secure high tide roosting area for birds, including migratory waders and vulnerable species such as the Terek Sandpiper, Little Tern and Beach Thick-knee. While the availability of other broadly similar roosting sites in the Darwin region suggests that the loss of North Shell Island should not have a major impact on any bird species, a monitoring programme should be established to clarify this issue particularly with regard to the Beach Thick-knee (refer to Chapter 6).

**Operational Phase**

Consideration of environmental impacts of the operational phase of the proposal on the terrestrial environment is not relevant, as Quarantine and North Shell islands will be converted into a major port and industrial facility, with virtually no remaining natural features.

The Master Plan (GHD 1993) provides for a waterway to be maintained between the port and Catalina Island. The Proponents will ensure that port activities do not intrude onto Catalina Island, in order to protect both the Aboriginal sacred site on the island and surrounding sandbar (refer to Section 5.5) and the island’s environmental values.

**5.2 ESTUARINE PHYSICO-CHEMICAL ENVIRONMENT**

The East Arm of Darwin Harbour is the estuary of the Elizabeth River. In common with most other estuaries, it experiences significant daily and seasonal fluctuations in salinity, depending on the rate of recent fresh water inflows and the tidal stage. The runoff contains suspended particulate matter, inorganic and organic nutrients and a wide range of other constituents (including wastes) derived from developed and undeveloped sections of the catchment. In addition, effluent from wastewater treatment lagoons at Palmerston and Berrimah is discharged into tidal tributaries of...
East Arm.

This section reviews the physical and chemical characteristics of the section of East Arm within the study area, and the likely effects of the proposal on these characteristics.

5.2.1 Existing Conditions

Bathymetry

Water depths in East Arm at low water are shown in Fig 5-5, which is reproduced from the AUS 28 Chart. The depth contours are based on surveys carried out up to 1984; however, a hydrographic study undertaken in 1990 as part of the ADDCAP site investigations (Acer Vaughan 1990b) suggested that the bathymetric regime of East Arm has been relatively stable over at least the past 20 years.

The main channel of East Arm maintains a clear depth of at least 15 m between the existing port and for a short distance after it passes to the south of South Shell Island. From this point the channel depth decreases progressively to about 2 m at a point to the south of Hudson Creek. A crescent-shaped sand bar extends about 4 km in a southeast to east direction from near the southern tip of South Shell Island. Water depths over the sand bar, which lies between the main channel and the proposed port area, are typically 0.6 to 3 m at low tide.

North Shell Island has a maximum elevation of 2 m above high water, while South Shell Island is completely covered during high tides. A relatively narrow 2 m deep channel between the Shell Islands broadens out and deepens to about 5 m as it extends towards the southeast and east between the sand bar and Old Man Rock. This secondary channel shelves to a depth of about 3 m as it merges with the main channel to the south of Hudson Creek.

Most of the area between North Shell Island and Quarantine Island which is to be filled to create the proposed port dries at extreme low tide.

Seabed Conditions

Information is available on geological conditions and sediment characteristics in the proposed port area (Acer Vaughan 1992b, 1992c). Additional drilling is being undertaken to provide a basis for the detailed engineering design of the current port proposal (Dames and Moore 1993).

Fig 5-5 indicates the distribution of surface sediments, based on analysis of samples collected from 33 sites (Acer Vaughan, 1990b). Sediments in the channels, which are exposed to higher current velocities, are composed
predominantly of coarse to medium grained gravels (2 to 10 mm) comprising shell fragments, laterite pisolitho and iron-stained rock fragments.

An extensive area of sand, comprising coarse to fine fragments of quartz, shells and other marine skeletal material, forms the large sandbar which extends about 4 km up East Arm from South Shell Island.

The marine sediments in essentially all areas outside the main channel consist of fine material (described generally as "mud") comprised of clay and silt.

The textural composition of sediment samples taken from the area to be dredged to form the channel and swing basin for the proposed port are as follows (refer to Fig 5-5 for the locations of these sampling sites):

- Site 9. gravel, 14%; sand, 86%; mud, 0%;
- Site 17. gravel, 8%; sand, 94%; mud, 0%; and
- Site 18. gravel, 58%; sand, 36%; mud, 6%.

This information suggests that the sediments in areas which are to be dredged contain only a very small proportion of fine material.

An analysis of mud deposits in Section 4.7 of the Master Plan Report (GHD, 1993) indicates mud depths of less than 1 m over the reef area between Quarantine and North Shell islands which will be covered by the proposed port (field observations during the EIS suggest that much of this reef area has little or no mud cover).

**Tides**

The tides at Darwin are among the largest on the Australian coast, and the tidal water movement has a large influence on the shape, seabed characteristics, current dynamics and water quality of Darwin Harbour. Tidal planes listed in the Master Plan (GHD 1993) for the study area are as follows:

<table>
<thead>
<tr>
<th>Tide</th>
<th>Chart Datum</th>
<th>AHD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highest Astronomical Tide (HAT)</td>
<td>7.9 m</td>
<td>3.92 m</td>
</tr>
<tr>
<td>Mean High Water Springs (MHWS)</td>
<td>6.9 m</td>
<td>2.92 m</td>
</tr>
<tr>
<td>Mean High Water Neaps (MHWN)</td>
<td>5.1 m</td>
<td>1.12 m</td>
</tr>
<tr>
<td>Mean Sea Level (MSL)</td>
<td>4.1 m</td>
<td>0.12 m</td>
</tr>
<tr>
<td>Mean Low Water Neaps (MLWN)</td>
<td>3.2 m</td>
<td>-0.78 m</td>
</tr>
<tr>
<td>Mean Low Water Springs (MLWS)</td>
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<td>-2.58 m</td>
</tr>
<tr>
<td>Lowest Astronomical Tide (LAT)</td>
<td>0.1 m</td>
<td>-3.88 m</td>
</tr>
</tbody>
</table>

Draft EIS - Darwin Port Expansion
East Arm

Acer Vaughan/
Consulting Environmental Engineers
(AV/532)
The spring tide range is 5.5 m and the neap tide range is 1.8 m. The tidal range regularly varies between spring and neap at approximately weekly intervals.

As a consequence of these large changes in water level every 12.4 hours, an enormous quantity of seawater enters and leaves East Arm. For the average tide, the daily tidal inflow and outflow is 216 million m$^3$ on a spring tide and 71 million m$^3$ on a neap tide, which represent 69 per cent and 29 per cent, respectively, of the average volume of East Arm at mean sea level (Caldwell Connell Engineers 1976).

The large tidal range is a significant percentage of the typical depth in East Arm, which implies that the tidal prism (the volume of water expelled from the estuary at the end of each ebb tide and returned on the succeeding flood tide) is also a significant percentage of the total volume of water in the estuary. It follows in turn that the water movement from high water slack to low water slack - the tidal excursion - must also be a large percentage of the total estuary length. As a practical matter, tidal excursions of up to 20 km were observed several times in float experiments at the mouth of Darwin Harbour on spring tides (Caldwell Connell Engineers 1976).

Comparisons between the recorded high water and low water tide heights and times at Stokes Hill Wharf and the predicted values has shown that deviations from the predicted tide heights and times were small (less than 0.2 m in height and less than 15 min in time). This indicates that meteorological effects on bulk water movement are generally insignificant compared to that induced by the tides (except at times of cyclones or other infrequent but major events).

Tide heights have been measured at several stations along East Arm. The results indicated only a very small change in the tidal range between the stations and a small lag in the time of occurrence of high water compared to that at Stokes Hill Wharf. The differences in times of high and low waters probably is within the limits of accuracy of recording (Caldwell Connell Engineers 1976).

**Storm Surge Levels**

Storm surge levels in the harbour are currently being reassessed on the basis of all available data (Acer Vaughan/Vipac (1993)). Interim results from this reassessment available at the time of printing indicate the following:

- 1:100 year event 4.1 m AHD
- 1:1000 year event 5.4 m AHD

These results compare with the 1984 "Greater Darwin Storm Surge Study" values of 5.1 m AHD for a 1 in 100 year event and 6.5 m AHD for a 1 in 1 000 year event.
Engineering planning and design will be based upon the confirmed results of the 1993 study once these are available.

**Stratification**

Density stratification through the water column can arise from either or a combination of temperature and salinity stratification. However measurements conducted in East Arm during the 1970s (Caldwell Connell Engineers 1976) found no vertical stratification due to solar heating during the dry season. The same study identified some temperature stratification during the wet season, reflecting the higher temperature of fresh water inflows; however the density stratification arising from this was insignificant compared to that arising from salinity stratification.

Salinity profiles during the wet season showed significant vertical stratification in East Arm and Middle Arm. At sites close to river or creeks discharging fresh water to the harbour, a classical two-layer salinity structure was evident. The depth-averaged salinity during the wet season shows a continuous decrease from the highest salinity at the ocean to freshwater in the rivers discharging to the harbour. (Caldwell Connell Engineers 1976).

**Hydrodynamics of Darwin Harbour**

A two-dimensional computer model developed by Acer Vaughan/Patterson Britton (1993) was used to predict tidal currents in Darwin Harbour with and without the proposed port. The model covers the whole harbour, including all the waterways and mangrove areas to a land level of about RL 11 m, and has been calibrated and verified using water level and tidal flow data collected during field exercises in January and April 1993.

The model established for Darwin Harbour is a finite element model which is used throughout the USA, where it was originally developed for the Corps of Engineers. The two-dimensional depth-averaged Navier Stokes equations are solved, with turbulent energy losses represented by an eddy viscosity analogy. Friction losses are treated by a Chezy or Manning formulation. Other terms in the equations account for Coriolis forces and wind surface stress.

The capabilities of the model include wetting and drying in portions of the network, simulating the wetting and drying of marsh and mudflat areas of an estuary during a tidal cycle or floodplain areas during storm events, and inclusion of wind stress. Coupled two-dimensional advection diffusion equations are used to represent dispersion. In formulating the equations, the element co-ordinate system is realigned with the local flow direction. This permits the longitudinal and transverse diffusion terms to be separated, with the net effect being to limit excessive constituent dispersion in the direction transverse to the flow.
Source pollutant loads may be input to the system either at discrete points, over elements, or as fixed boundary values.

Two series of field measurements were made in Darwin Harbour to calibrate and check the model. The first field exercise was conducted in January 1993 and comprised collection of water level data throughout the estuary and tidal velocity measurements in the vicinity of the proposed East Arm Port. A second field exercise was undertaken between 22 and 29 April 1993 in which water level, tidal velocities and water quality were monitored at various locations for springs to neap tidal ranges. The computer model was then calibrated and verified for water level and discharge over the tidal ranges surveyed during the January and April 1993 field data collection exercises.

For this EIS the Darwin Harbour computer model was used to predict current patterns on the flood and neap tides under ebb and Spring tides, with and without the proposed port.

Water movement in Darwin Harbour is dominated by the currents produced by the ebb and flow of the tides. During spring tides the peak inflowing current is 0.6 to 0.9 m/s throughout the channel in East Arm. The upper section of Figure 5-6 illustrates the existing peak inflowing current speed, with current speed intervals of 0.15, 0.30, 0.45, 0.60, 0.90 and 1.2 m/s shown in the figure. The current speed exceeds 0.9 m/s in the channel southeast of South Shell Island, and in the narrowing southward channel leading to the Elizabeth River.

Tidal excursions in East Arm, that is the distance travelled by a parcel of water during the flood or ebb tide, are typically 5 km in neap tides and 12 km in Spring tides. Currents in Middle Arm are faster than in East Arm, with the speed in the whole of the Middle Arm channel exceeding 0.9 m/s.

The upper section of Figure 5-7 illustrates the peak existing outflowing current speed with the same contour intervals as for the flood tide. During Spring tides the peak outflowing current is 0.6 to 0.9 m/s throughout the channel of East Arm. The regions where outflowing current speeds exceed 0.9 m/s are to the southeast of North and South Shell Islands, and in the narrowing southward channel leading from the Elizabeth River.

Some of the mangrove creeks extending off the main channel of East Arm also have relatively fast currents, generally peaking at around 0.6 m/s on spring tides.

Mass water movement in East Arm and Darwin Harbour in general is dominated by the tides hence the movement is oscillatory with a period of approximately 12.4 hours. During the wet season, the rivers flow seaward into their estuaries adding a constant seaward component to the oscillatory motion so that the ebb excursion is
greater than the flood excursion.

**Water Quality**

A number of water quality investigations have been carried out in Darwin Harbour over the past 15 years (Dames & Moore 1992), the most recent being a study at 11 sampling stations by the Power and Water Authority between December 1986 and May 1998 (Power and Water Authority 1990). That study focused on the dry-wet transitional period (September to April) and samples were collected on ebb tides in order to obtain information on the effects of catchment land use on water quality.

The water quality parameter of most relevance to the East Arm Port proposal is turbidity, which results from light scattering by fine suspended material in the water column. Turbidity is an important controlling factor in the distribution of marine organisms, because of: (1) its close relationship with light penetration; (2) inorganic and organic nutrients and trace elements which tend to be associated with particulate matter; (3) the potential effects of high levels of suspended solids on filter-feeding organisms; and (4) the potential effects of the deposition of solids on benthic (bottom-dwelling) plants and animals.

The Power and Water Authority study showed that turbidity in the harbour varies greatly from site to site and season to season. The highest turbidities typically occurred during the wet season, in the middle reaches of East and Middle Arms where high tidal currents generate turbulence which tends to resuspend particulate matter from the bed of the estuary. Turbidities ranged between 0.9 and 28.0 NTU at the 11 sampling stations (overall mean 5.9 NTU). The mean turbidities (and ranges) for the three sampling stations in East Arm were as follows:

- Site 1 (50 m upstream from the Elizabeth River Bridge) 5.4 (1.4-15) NTU;
- Site 2 (in the main channel across from the Quarantine Island boat ramp) 8.2 (1.6-21) NTU; and
- Site 11 (at the mouth of “Creek H” on the southern side of East Arm approximately 3.5 km downstream from the Elizabeth River Bridge) 6.3 (2.0-13) NTU.

The sampling station recording the highest turbidity was in Middle Arm, approximately 2.5 km west of Channel Island, where the respective values were 10.2 (1.7-24) NTU.

**5.2.2 Environmental Effects**

This section reviews the environmental effects of the construction and operation of
the proposed port on the marine physico-chemical environment.

The lower section of Figure 5-6 illustrates the predicted peak outflowing current speed after Stage 3 of the port development, with current speed intervals of 0.15, 0.30, 0.45, 0.60, 0.90 and 1.2 m/s shown in the figure. The current speed exceeds 0.9 m/s beside the wharf, and in the narrowing southward channel leading to Elizabeth River. There is no significant change in the flood tidal current pattern in Middle Arm or in the area to the west of the port. However, as might be expected, there are significant changes southeast of South Shell Island, where the peak current speed decreases due to the larger channel area available.

There are also weaker currents in the lee of the port (to the northwest), and generally sedimentation in these areas over time is expected. Tidal excursions in East Arm, that is the distance travelled by a parcel of water during the flood or ebb tide, will decrease slightly, but this will not have any significant effect on dispersion or tidal flushing.

The lower section of Figure 5-7 illustrates the peak predicted inflowing current speed with the same contour intervals as for the flood tide. During spring tides the peak outflowing current will be spread over a slightly wider channel, with weaker currents in the vicinity of South Shell Island, but a peak current of 1.2 m/s beside the wharf.

The promontory located approximately 4 km southeast of the Quarantine Island boat ramp (referred to hereafter as the southeast promontory) will experience higher current speeds, particularly on the ebb tide. There also is predicted to be a significant shift in current patterns, and an increase in current speeds in the mangrove creeks south of the port (in the Paspaley Pearling Lease area). These will alter sediment patterns in that region, and increase the rate of erosion of the southeast promontory.

Changes in Currents in Vicinity of Catalina Island

Concern has been expressed by the Aboriginal Areas Protection Authority regarding the influence of the East Arm Port project on the sandbars around Catalina Island, which is about 750 m southeast of Quarantine Island. For a spring tide, the model predicted increases in peak flood and ebb tidal velocities on the southern and eastern sides of the island. It is likely that these higher velocities will result in some erosion of sediments around the island.

For Stage 1 of the East Arm Port, the change in velocity is very small. However the proposed ultimate development would involve fill extending close to the western shore of the island. This stage would cause significant changes in tidal velocities around Catalina Island. The Darwin Harbour model was used to simulate existing
and proposed tidal velocities at three locations around the island to assess the likelihood of change to the sandbars. This is included in Appendix F in a letter from Patterson Britton and Partners, dated 27th September 1993.

East of the island, the flood tidal velocity would increase from about 0.35 m/s to near 0.6 m/s. South of the island, the flood tidal velocity would increase similarly to Location C while the ebb currents would change marginally. Between the island and the proposed landfill, the ebb velocities would increase from around 0.2 m/s to 0.4 m/s although this increase would be dependent on the size of the channel established between the two landbodies.

The predicted change in flood tidal velocities east and south of the island have potential to scour the sand bar depending on the characteristics of the sediment. Sand transport as bed load typically occurs for tidal velocities above 0.3 m/s, depending on the grain size. However, if the shoal has a gravel or shell armour then the increase in tidal velocities would be much less likely to erode the shoal. Investigations into the content of the shoals around Catalina Island will be necessary to confirm the sediment characteristics prior to construction of Stage B in order to assess the future impact on this area.

Modelling of Turbidity Levels During Construction

The construction of the East Arm Port will involve the dredging of sediment and its placement into a banded sedimentation pond within the landfill area. Excess water will be returned to the harbour. The dispersion and advection behaviour of this suspended sediment plume was modelled to identify its path and its influence on background suspended solids concentrations in East Arm. Suspended solids concentration contours were produced for a simulated six day period for a spring tide for the Stage 1 and Final development scenarios.

An extension of the computer model was used to predict the distribution of suspended solids derived from dredging and discharge of return dredge water from the settling basins on the port site. A number of parameters were adopted to describe the likely suspended sediment plume. These were:

• dredge return water discharge point from proposed landfill into the harbour to be located at mid point of Stage 1 reclamation;
• mean diameter of suspended sediment in the return water is 0.02 mm;
• suspended sediment concentration in return water is 5,000 mg/L;
• discharge rate for return water is 1.5 m$^3$/s;
• background suspended sediment concentration is 20 mg/L;
• kinematic viscosity of suspending sediment is 1.16 x 10$^{-6}$ m$^2$/s;
• density of sediment is 2.70 kg/m$^3$;
• critical shear stress for erosion is 0.06 newtons/m$^2$;
• bed roughness is 0.01 m; and
- wave induced suspension of sediment would be neglected.

The hydrodynamic model was run for 150 hours (over 6 days) with a constant spring tidal range input for both the Stage 1 and Ultimate proposed developments to establish the velocity fields within the area of interest. The sediment model was used to simulate the dispersion and advection of the suspended solids plume from the construction activity.

This represented a conservative examination of the issue as it does not allow for settling of suspended sediment and as such tends to overstate the likely suspended sediment concentrations due to construction activities. Also it assumes a constant spring tide boundary input which would overstate the dispersion and longitudinal travel of the plume.

For the first few days, the plume would tend to remain on the northern side of the estuary travelling both upstream and downstream with the prevailing tidal currents. The suspended solids concentration contours have been plotted at times of 66, 72, 144 and 150 hours and are presented in Appendix F.

A sample contour plot of suspended solids concentrations at high tide after about a week of dredging is shown in Figure 5-8. This plume would tend to disperse to a large degree within the upper part of East Arm although the increase in suspended solids concentration on the southern side of East Arm (in the vicinity of the Paspaley Pearling lease) would be much smaller than the values near the port site. After 150 hours of simulation, the predicted concentration in the vicinity of the Paspaley lease had increased to about 30 mg/L from a background value of 20 mg/L. The concentrations in this area are highest during an ebb tide, and appear to gradually increase with time.

With continuous dredging over several months, it can be anticipated that the whole of East Arm upstream from the port will have higher turbidity levels for both Stage 1 and Ultimate Development, assuming similar extended dredging activities are involved in each stage.

Summary of Impacts on Physico-Chemical Conditions

Based on the information available and the computer model predictions, the following effects are anticipated as a result of the port development:

1. Lower tidal velocities and sedimentation in the lee of the port (ie, to the northwest and northeast of the port);

2. Higher ebb tide velocities adjacent to the southeast promontory, and gradual erosion of that promontory;
3. Changes in the current patterns, and consequent changes in sediment distribution, in the mangrove creeks south of the port.

In summary, the port will alter current patterns in East Arm and there will be a gradual change in sediment distribution to a new equilibrium. A slow rate of change is expected because of the small supply of sediment to East Arm.

During the construction phase, there will be elevated turbidity through the whole of East Arm upstream from the port. Any increases in turbidity is likely to be accompanied by slightly elevated heavy metal concentrations in the water column as fine sediments in Darwin Harbour tend to contain low, but significant concentrations of metals (of natural origin). However, the extent of any such increase will be limited because of the low proportion of fines in the material to be dredged.

5.3 ESTUARINE BIOLOGICAL ENVIRONMENT

This section describes the findings of the marine environmental studies which were undertaken as part of the EIS programme, and assesses the likely environmental impacts of the construction and operation of the port facility on the marine biota.

5.3.1 Existing Conditions

The major physico-chemical conditions affecting existing marine biota in the East Arm and elsewhere in Darwin harbour are the large tidal variation, seabed composition, bathymetry (water depth) and water quality.

- The characteristics of the tides in Darwin are discussed in Section 5.2. The large tides create very strong tidal currents in the arms of the harbour, and result in large areas of Darwin Harbour (and associated marine biota) being alternately covered by up to 7 m of seawater at high tide, and exposed to air, high temperatures and sunlight at low tide. The large tides also result in substantial exchange of water mass between the arms of the Harbour, and between Darwin Harbour, Beagle Gulf and the Arafura Sea. Hence, plankton, pelagic and planktonic larval dispersion are influenced by the effect of mixing and exchange of water masses.

- The characteristics of the seabed in Darwin Harbour and in the vicinity of the port development are discussed in Section 5.2. The seabed in the vicinity of the Port Development, like that elsewhere in Darwin Harbour, is characterised by a diverse mosaic of intertidal mudflats, coral rubble banks and rock reef, sand banks, rocky islands, coral rubble slopes and channel beds, and muddy and sandy seabeds. Hence, there is a variety of seabed
habitats available to marine biota at various depths in Darwin Harbour.

- Water quality parameters which affect the pattern of distribution biota in Darwin Harbour include turbidity (and light penetration), temperature, salinity and nutrient concentration. Turbidity in Darwin Harbour is naturally high due to suspension and resuspension of sediments from the extensive mud flats by tidal currents and wind waves, and from suspended solids in storm runoff. The natural turbidity and its effect on light penetration in the Harbour appears to be a major factor limiting primary productivity in the harbour waters. The high natural turbidity is responsible for the vertical compression of coral, seaweed and sponge/gorgonian zonation in the Harbour (Caldwell Connell Engineers 1983), and generally restricts the range of habitats suitable for hard corals and seaweeds to the intertidal and shallow subtidal areas of rubble and reefs.

- Temperature and salinity vary with the season. Nutrients are locally influenced by point sources (sewage outfalls), and freshwater runoff during the Monsoons, and are more generally influenced by the exchange of water between the Harbour and Beagle Gulf and the Arafura Sea.

Hence, biota which require light (plants and hard corals) are restricted by the natural turbidity. Settlement of suspended sediment also affects plants and animals on the seabed. Seasonal variations in temperature, salinity and nutrient affects the occurrence and abundance of short-lived plants and animals.

Overall, the biological characteristics of Darwin Harbour comprise a diverse mix of tropical marine and estuarine biota. The biological components of Darwin Harbour may be divided into the following associations:

- Mangroves;
- Soft Seabed Biota;
- Pelagic Biota;
- Plankton;
- Hard Seabed Biota;
- Marine Mammals; and
- Marine Reptiles.

The characteristics of these components in Darwin Harbour and in the vicinity of the port relocation site is discussed below.

This section reviews the main components of the estuarine ecosystem in the vicinity of the East Arm port site, and assesses the likely effects of the proposal. A number of coral reefs in other sections of the harbour were also surveyed as part of the field investigations for comparative purposes.
**Mangrove Communities**

The tidal forests of Quarantine Island occupy well defined zones arranged roughly parallel to the shoreline. Known as zonation, this vegetation patterning is common in mangrove forests and is related to the level of the substrate and the frequency of tidal inundation. The zones, often dominated by a single mangrove species, lie in a typical sequence from the seaward fringe to the landward margin. Zonation patterns for Darwin harbour mangroves have been described by Semeniuk (1985) and Woodroffe and Bardsley (1988). Transects through the intertidal zone on the south western and north eastern shores of the island showing the pattern of zonation and expected elevations (after Woodroffe and Bardsley 1988) are shown in Fig 5-3.

**The Sonneratia Zone.** The Sonneratia Zone is the most seaward zone and characterises the open shore of East Arm. The zone is dominated by large, well-spaced individuals of Sonneratia alba up to 12m tall rooted in unconsolidated mud. Associated with this zone is an intermittent shrub layer of Aegiceras corniculatum (to 2m tall) with some scattered Aegialitis annulata particularly where the substrate is rocky.

The Sonneratia zone lies between -3.3m and 0 m AHD and is consequently inundated by every tide. The next zone to landward is usually the Rhizophora Zone and there is some overlap of the two species where this transition occurs. However, in the more protected bays and outlets of major tidal channels, a mixed tidal creek assemblage is found.

**Tidal Creek Zone.** The Tidal Creek Zone is characterised by tall Rhizophora stylosa and Avicennia marina growing in soft, deep muds at the mouths of protected bays and tidal inlets. Figure 5-2 shows that this mangrove assemblage is only found at the north eastern end of the development site.

Tidal Creek mangrove has a well developed structure with an abundance of large, mature trees and a diverse understorey. The size and age of many Rhizophora and Sonneratia trees indicates that they successfully survived Cyclone Tracy.

The substrate is often moderately to steeply inclined and the understorey layer dense. Common mid-stratum species include Camptostemon schultzii and Aegiceras corniculatum - two species that were not commonly found elsewhere on the survey site. Aegialitis annulata and Bruguiera parviflora were also scattered through the Tidal Creek Zone.

**The Rhizophora Zone.** Large areas of mangal included in this zone are presently devoid of vegetation as a result of cyclone damage (Attiwill and Clough 1976; Stocker 1976). The Rhizophora Zone frequently contains the tallest trees in the
mangrove (to 16m in East Arm) and is consequently more susceptible to cyclone damage. In addition, Rhizophora stylosa can only regenerate from apices on very small branches - most of which are stripped from the trees by a cyclone - resulting in extensive areas of post-cyclone dieback. Before Cyclone Tracy struck in 1974 the bare areas of mud now found in this zone supported a forest of mature Rhizophora stylosa. Remnant tall Rhizophora stylosa are scattered throughout the zone and occasional monospecific stands are still present, particularly along the landward margin of this zone.

The Rhizophora Zone lies roughly between mean sea level (0m AHD) and 1.5m AHD (Woodroffe & Bardsley 1988) and to landward merges into a thicket of mixed mangrove referred to here as the Bruguiera Zone (Fig 5.2).

The Bruguiera Zone. In this narrow but distinctive zone Rhizophora stylosa is also the dominant species but here forms dense thickets with Bruguiera parviflora.

Other associated species include Bruguiera exaristata and Avicennia marina. Locally these species most frequently occur within the elevational ranges 1.5 to 2.0m AHD (Woodroffe & Bardsley 1988). R stylosa and B. parviflora are dominant lower in the tidal range with B, exaristata and Avicennia marina becoming more common to landward.

The Ceriops Zones. Above approximately 2m AHD in elevation the Bruguiera Zone merges into the Ceriops Zone where Ceriops tagal var. australis becomes the dominant species. In the Ceriops and Avicennia Zone (Figure 4), Ceriops forms low closed thickets (to 4m) with less dense but taller Avicennia marina interspersed throughout. Other common, associated species include Bruguiera exaristata and Aegialitis annulata.

Further up the tidal range Ceriops forms increasingly monospecific stands. Avicennia marina decreases in abundance and Ceriops tagal decreases steadily in height often to less than 2m or lower around bare salt flats. Also within the Ceriops Zone is evidence of cyclone damage. Variable in both location and extent these numerous bare areas are characterised by the abundant bleached trunks of fallen Ceriops trees, often still aligned in the direction of windthrow (south to north).

Salt Flats. A feature of Quarantine Island is the extensive system of salt flats on the western slope. These salt flats occur near 3m AHD and separate the mangrove zones of the seaward, frequently inundated habitats, and the landward mangroves which receive less than 20% of all tides in a year.

The salt flats are largely devoid of vegetation with the exception of the chenopods Sueda arbusculoides and Halosarcia sp. Small areas of mangrove shrubland occur where minor variations in salt flat topography occur. These stunted communities are
dominated by Avicennia marina with scattered Ceriops tagal and Aegialitis annulata.

**Avicennia Zone.** On the margins of the salt flats Avicennia marina (to 2m) may form a distinct community separating the salt flats from the Ceriops Zone.

This zone is largely monospecific and individual trees are rarely taller than 3m; often becoming progressively shorter and more stunted closest to the salt flat margin.

**Mixed Mangrove.** To landward of the salt flats on the western shore, the zonation pattern becomes more complex and the numbers of coexisting species increases. Avicennia marina often dominates mixed mangrove associations with Ceriops tagal, Bruguiera exaristata and Lumnitzera racemosa in various levels of codominance.

Ceriops tagal and Bruguiera exaristata often grow together in this zone forming tall stands to 10m. These stands were severely affected by Cyclone Tracy and the present forest is interspersed by numerous patches of debris-strewn dead areas (Fig 5.2).

**The Hinterland Margin.** The rear zone of mangroves lies at about 3.6m AHD and receives only 3.5% of annual high tides which occur during the wet season months (Woodroffe & Bardsley 1988). The landward fringe of the mangrove community is often moderately sloping and influenced by some freshwater seepage and sediment sheetwash from the hinterland (Semeniuk 1985). The mangrove assemblage here is dominated by Excoecaria ovalis and Lumnitzera racemosa. Ceriops tagal, Bruguiera exaristata and Avicennia marina are common, associated canopy-forming species. Occasionally Xylocarpus mekongensis and Thespesia populnea were also found at the landward extreme of the mangrove.

The hinterland fringe varies in extent from a broad band over 20m wide to a narrow belt only a few trees in width.

**Rocky Shore Zone.** At the southern end of Quarantine Island, both east and west of the boat ramp, are sections of sloping rocky shores. Here, mangrove soils often have a pebbly framework with patchy interstitial mud and the community is exposed to some wave action. The mangrove community found to landward of the Sonneratia and Rhizophora Zones is a mixed assemblage with Rhizophora and a large variety of associated species.

Aegialitis annulata, Camptostemon schultzii, Osbornia octodonta, Avicennia marina, Aegiceras corniculatum and Bruguiera exaristata were recorded at mid to low tidal elevations in the Rocky Shore Zone. Excoecaria ovalis, Lumnitzera hydrophyllacea are common species to landward.
Mangroves of the East Arm Islands. Figure 5-4 shows the distribution of mangrove communities found on the three islands of the East Arm Peninsula region.

- Catalina Island. The surrounding mangrove community is largely a mixed assemblage typical of the Rocky Shore Zone with a narrow Sonneratia Zone to seaward. Nine mangrove species were recorded on Catalina Island (Appendix A).

- North Shell Island. The intertidal mangrove community partly encircles the shell ridge with Sonneratia and Rhizophora zones to seaward and Avicennia-dominated mixed mangrove higher up the tidal range. Aegialitis annulata is an abundant understorey species throughout most of the mangrove zones as it is well adapted to rocky substrates. Large Osbornia octodonta are a feature of North Shell Island; spreading shrubs to 3m tall grow amongst Avicennia and Ceriops tagal adjacent to the shell ridge.

- South Shell Island. The vegetation found on the rocky substrate of South Shell Island is a mangrove assemblage comprised of four species. The maximum elevation probably lies between mean sea level and 1m AHD as only Sonneratia alba, Aegiceras corniculatum, Camptostemon schultzii and Rhizophora stylosa occur here. These species are usually restricted to the seaward mangrove zones and here would receive inundation by every tide.

The South Shell Island mangrove is dominated by a dense shrub layer of Aegialitis annulata to 1.5m with occasional Sonneritia, Rhizophora or Camptostemon to 2.5m.

Soft Seabed Biota

There are extensive areas of intertidal mudflat in Darwin Harbour. The mudflats are inhabited by burrowing invertebrates including worms, small crustaceans and bivalve shellfish. Generally the diversity and abundance of these fauna in the intertidal mudflats appears to be low based on Middle Arm data (Caldwell Connell Engineers 1983, Consulting Environmental Engineers 1986) compared with the fauna of the muddy seafloors below the low tide mark which has recently been extensively sampled by scientists at the Museum of the Northern Territory. The abundance of biota appears to be patchy and variable, although the overall characteristics from mudflat to mudflat appear to be similar (Consulting Environmental Engineers 1986).

Figure 5.5 shows that there are extensive mudflats in East Arm to the northwest, east and south of the proposed development. There are also extensive mudflats in other sections of the harbour. Although there are no known comparative data from...
Middle, East and West Arms, it is expected that the biota of the intertidal mudflats around Darwin Harbour are generally similar due to the strong tidal exchange and mixing, similar sorting of sediments, and similar regional habitat characteristics. However, local inputs such as sewage discharges, creeks and drainage channels may influence the composition of the biota to some extent (eg, Hanley and Couriel 1991).

As part of a Harbour wide, interdisciplinary workshop in July 1993, the Museum of the Northern Territory collected 300 soft sediment samples from 200 subtidal seabed locations around Darwin Harbour. The samples are presently being analysed, and indicate that there is a rich and diverse fauna of invertebrates in the muddy subtidal seabed of the harbour. Little information is available on the biota of areas of coarse mobile sand in the harbour.

Fish

There is an extremely wide variety of fish in Darwin Harbour, ranging from the pelagic sharks, mackerel, queenfish, threadfin salmon, jewfish and barramundi, to snappers, coral trout, cod, emperors, garfish, mullet and bream, and more sedentary smaller fish such as gobies, cardinal fish and coral fish. The various species of fish appear to be widespread around Darwin, with individual species having particular habitat preferences such as deep channels, rock outcrops, mangrove creeks and coral and sponge garden areas.

The reefs, channels and coral and sponge gardens in the vicinity of the Shell Islands provide diverse habitats for fish. The fish species associated with the Shell Islands should be similar to those found elsewhere in Darwin Harbour although the proportion of species present at each site is likely to vary according to the habitat characteristics. The Museum of the Northern Territory conducted a series of beam trawls for small fish at various locations around Darwin Harbour as part of the July 1993 AMSA workshop, and included some trawls close to the Shell Islands. However, the samples are presently being sorted and processed, and as yet no comparative data are available on the fish assemblages at the various sites.

Plankton

Although it is widely recognised that mangrove leaf fall represents the major source of organic material for the Darwin Harbour ecosystem, phytoplankton (microscopic plants) are also an important primary producer. Phytoplankton respond to increases in nutrient concentrations (where natural nutrient concentrations are limiting), while zooplankton (microscopic animals in the water column) respond to increases in phytoplankton biomass and other suitable foods.

Phytoplankton biomass was monitored at a number of sites in Darwin Harbour by
measuring chlorophyll-a concentration from December 1986 to May 1988 (PAWA 1990). The data show that phytoplankton biomass is generally low, with maximum concentrations recorded in inlets, and minimum concentrations recorded in the deep main channels of the harbour. The phytoplankton of the shallow inlets are likely to be quite different from those of the main channels and will reflect local influences including catchment conditions and effluent discharges.

Studies in Middle Arm indicated that the zooplankton communities of the larger channels were characteristic of open ocean waters and that exchange with the Arafura Sea is substantial (Caldwell Connell Engineers 1983). Examination of samples collected in inlets in Shoal Bay during the same study indicated that the plankton communities of the shallow bays and inlets were different from the deep channels and reflected local influences including mangrove associations, catchment conditions and sewage effluent discharges. In both instances, zooplankton biomass was high, particularly during the monsoon season, probably in response to increased food supplies contained in storm runoff.

Hence the plankton characteristics vary in response to: (1) local influences, and (2) the degree of exchange with open ocean waters. It is apparent that the plankton in the main channels of East Arm are mostly likely to be of oceanic origin, with a smaller contribution from the mangrove creeks and inlets.

**Hard Seabed Biota**

Darwin Harbour supports an abundant and diverse range of biota associated with the rocky and coral rubble seabeds including corals, fish, sponges, anemones and gorgonians. The reefs are scattered throughout Darwin Harbour, and provide a habitat for small fish which are preved on by larger fish such as jewfish, barramundi, snapper and sharks.

The corals and shallow reef communities in Darwin Harbour are an important component of the Harbour's ecosystem, but it is apparent that their distribution is limited by natural factors including: (1) availability of suitable substratum; and (2) low light penetration due to high turbidity. The high turbidity limits most benthic plant and coral growth to approximately 7 m below mean sea level (Caldwell Connell Engineers 1983). Hence the corals and associated flora and fauna are only found in abundance on suitable seabed, and in the relatively narrow 3 to 4 m depth zone below the low spring-tide mark. Below this depth, sponges and gorgonians and other organisms which do not require light for photosynthesis are dominant.

The only documented biological surveys of hard seabed communities in Darwin Harbour were undertaken by marine biologists on Channel Island reef during preparation of the Channel Island Power Station EIS (Caldwell Connell Engineers...
Local marine biologists from the Museum of the Northern Territory, Northern Territory University and Conservation Commission, dive operators from Coral Divers and collectors at Indo-Pacific Marine are generally of the opinion that the most significant hard coral communities are located at Lee Point, Nightcliff, East Point, Weed Reef, Channel Island and South and North Shell Islands. They also consider that the characteristics of the marine biological assemblages at the Shell Islands are different from those outside the harbour, due possibly to the effects of higher turbidity, freshwater influence and water current regime. Over the years, various unusual species have been collected from the Shell Islands locality. In the past, several species were collected for the first time in this area (for example, the dwelling shrimp *Typton anomala*), and the unusual tropical leafy seadragon was collected on several occasions prior to 1980.

The physical factors affecting the biota of the Shell Islands certainly appear to be substantially different from those outside the harbour. Within the harbour the main channels of Darwin Harbour are bounded by mudflats in many places, receive storm runoff, and funnel tidal flows into strong currents.

Due to the potential impacts of the development on the Shell Islands and the interest in the biological assemblages of the area by local marine biologists, naturalists, divers and teachers, more detailed marine biological investigations were undertaken during the EIS in the vicinity of the Shell Islands.

**EIS Studies.**

Marine biological studies during the EIS focussed on the hard coral zone since this was considered by local marine biologists and naturalists to be the most limited biological assemblage in the harbour. During the studies, CEE's marine biologists dived at a total of 28 sites in Darwin Harbour over two 4 day periods of neap tides from 16 to 21 May, and 12 to 15 August 1993. The locations of the biological investigations are shown in Figs 5-9 and 5-10. Over 25 genera of coral taxa were observed during the survey (Table 5.1), with most of the corals being found at most of the sites although the proportions at each sites were generally different. *Turbinaria* was the most commonly recorded hard coral, and was recorded in most abundance at the Shell Islands.

The marine biological studies by CEE's marine biologists were undertaken in two phases. The conduct and results of the marine biological studies are discussed below.

The first phase of the study provided general information on the characteristics of the marine biological communities in the vicinity of the proposed port and at several other locations for general comparative purposes. The study involved semi-quantitative biological surveys of representative locations around the Shell
Islands, including Old Man Rock, Catalina Island and Quarantine Island, and at the Naval Base Breakwater, Fort Hill Wharf pilings, Weed Reef, and Channel Island. The locations of the semi-quantitative marine biological investigations in the vicinity of the proposed port relocation are shown in Figs 5-9 and 5-10. At each location a 50 m measuring tape was laid along the seabed extending out from the low tide mark, perpendicular to the depth contours. Marine biologists using SCUBA swam along the tape noting the changes in water depth and general composition of the benthic biological assemblages with distance along the tape.

The second phase of the study was undertaken to enable the characteristics of coral assemblages at the Shell Islands to be compared with those at other locations in Darwin Harbour. This involved identifying other locations around Darwin Harbour where significant coral assemblages occurred, and conducting quantitative surveys of a representative site at the Shell Islands and at other prime locations for coral in Darwin Harbour. The locations of the quantitative marine biological investigations are shown in Fig 5.9. At each location, five 20 m long transects marked at 1 m intervals were laid along the seabed extending out from the low tide (springs) mark, perpendicular to the depth contours. Marine biologists using SCUBA swam along each transect and recorded the depth and organism located under each 1 m interval marker. Hence at eight sites around Darwin Harbour, the biota at a total of 105 points at corresponding depths were recorded. The results of the studies are discussed below.

Shell Islands Habitat and Marine Biota.

The area of East Arm involved in the port relocation is shown on the infra-red photograph in Fig 5-11. The figure shows that the proposed port development will extend over North Shell Island and a large area of intertidal coral rubble, sandy and silty seabed extending from North Shell Island to a point close to the west of Catalina Island. Dredging of the seabed will widen and deepen the existing channel between North and South Shell Islands, and extend eastward almost as far as Old Man Rock. The northern edge of the intertidal area of South Shell Island will be removed, but the remainder of the island will remain relatively intact. Hence much of the development involves covering or removing hard seabed habitat.

Initial observations of the biota in the vicinity of South and North Shell Islands in May 1993 by marine biologists (Figs 5-9 and 5-10), showed that parts of the shallow, hard seabed were characterised by a relatively rich and diverse fauna of corals (with Turbinaria being most conspicuous as well as Favia, Favites, Goniopora) and associated fish, algae and invertebrates. Local marine biologists and divers considered that the characteristics of the coral and associated biota around the Shell Islands are different from other coral communities in Darwin Harbour (eg Channel Island), although no comparative studies had been undertaken before this study.
Biological communities inhabiting the hard seabed around South and North Shell Islands comprise a diverse range of hard coral, soft coral, algae and other invertebrate species. Although each of the sites surveyed was characterised by a unique combination of flora and fauna, a generalised depth-related pattern of distribution was discernible (Fig 5-12).

High on the shore, above the level of mean neap low tides (0.9 m below mean sea level (MSL)), exposure to the air can be frequent and long and very few benthic species can survive. Oysters, which prefer an intertidal habitat, encrusted the boulders and rocky outcrops in the high-shore zone. The sand among the boulders was mostly bare.

The zone between mean neap low tide level (0.9 m below MSL) and mean spring low tide level (2.8 m below MSL) is exposed frequently. Barnacle-encrusted rocks, coral rubble and fine silt/sand characterised this zone. Various species of seaweed grew in the silt and sand or attached to the coral rubble. Soft corals, mostly Sarcophyton or Lobophyton, were scattered around in low numbers. A few stunted hard coral colonies showed this zone to be the upper limit for survival of hard corals.

The seabed between mean spring low tide level (2.8 m below MSL) and lowest astronomical tide level (4.1 m below MSL) is exposed only infrequently for short periods. The greater variety of sessile biota living here reflected the less harsh conditions of this zone. In the upper 1 to 1.5 m of this zone, hard coral colonies were more common, although still quite small. These colonies were generally isolated and attached to moveable substrate or were free living. Dome-forming corals such as Favia, Favites and Goniopora were most common. Plate-forming corals such as Turbinaria were rare. Sizeable patches of bare coral rubble and fine silt/sand were numerous. Seaweed was common in these patches, either attached to the rubble or anchored in the sand. Other invertebrates also inhabited this region, although their small form and low numbers rendered them less conspicuous. Hydroids, small encrusting sponges, small ascidians and bryozoans were among the diverse range of small, sessile invertebrates revealed by careful observation.

Below the level reached by the lowest astronomical tide (4.1 m below MSL) the seabed is submerged almost constantly. Consequently exposure to the air becomes less important in determining the distribution of a species in this zone, and turbidity (due to its effect on transmission of light through the water) is the dominant physical factor. The depth range habitable by organisms dependent on sunlight for survival (including seaweeds and hard corals) extends only down to about 6 m below mean sea level (MSL) in most of Darwin Harbour, for this reason.
A pattern of variation over depth is thus evident in the dominant biota within this zone.

Hard coral colonies were larger and more prevalent on the seabed below lowest astronomical tide than in shallower waters. Plate-forming corals, such as *Turbinaria* and *Echinophyllia*, first appeared in this zone. These colonies were generally smaller than those in deeper water, however, and were interspersed with coral rubble, small coral boulders, shell sand and a diverse range of other sessile biota. Dome-forming colonies, including *Favia* and *Goniopora*, were common. These corals were attached to coral rubble, or were part of larger coral bommies (boulders and pillars formed by coral skeletons). Seaweed, encrusting sponges, bryozoans and other biota covered much of the remaining substrate. Hydroid trees, soft corals, anemones, solitary ascidians and solitary sponges, and the conspicuous tubes of the worm *Eunice tubifex* were common. Free-living hard corals, such as *Herpolitha* and *Fungia* were found on patches of open sand, and large solitary coral polyps (family Cyana). occurred occasionally. Mobile invertebrates, such as nudibranchs (sea slugs), feather stars, and sea urchins could be spotted. Various species of fish were present in low numbers, including Scribbled angel, Chelmon, blue tusk, and clown fish.

Moving into deeper water, toward the lower limit of hard coral growth (6 m below MSL), the sessile community became increasingly prolific and diverse. The hard coral *Turbinaria* formed large vase-shaped colonies. *Goniopora* and *Favia* were common as broad dome or large flat colonies. Coarse sand comprised most of the substrate, although there were very few bare patches. Outcrops or bommies formed mostly by the hard coral *Symphyllia* provided extensive habitat for a colourful and assorted assemblage of animals. Some of the 25 species of coral recorded during the Harbour-wide survey could be found in various densities in this region. Most obvious among the dome-forming species were *Euphyllia* and *Galaxea*. *Echinophyllia* (plate forming) and the branched coral *Duncanopsammia* were representative of other structural types. Free-living *Herpolitha* and *Fungia* corals were common between coral outcrops. In addition to the hard corals, specimens of most other invertebrate species found associated with coral communities in East Arm could be found in this depth range.

Various seaweeds, sponges, lobate soft corals (*Nepthya*) and *Eunice tubifex* worm tubes populated any bare sand patches. Byrozoans, ascidians, encrusting sponges, tube worms, seaweeds, anemones, soft corals and hydroids grew attached to the coral boulders. The large sponges which dominated the communities in deeper water also occurred in this region, although smaller in form. Colourful branched sponges, large basket forms and broad fan sponges were moderately common among the hard coral colonies. The striking-looking gorgonian corals abundant in deeper water first appeared in this zone: white and orange whip-corals, orange and red lyre and fan gorgonians were sparse but
conspicuous. The mobile invertebrates and many species of fish seen in the shallower zone also were common in the deeper water.

Beyond the hard coral zone (6 m below MSL) sponges and gorgonian corals dominated the sessile biota. The seabed was mostly bare sand with small coral boulders and patches of rubble. Large fan sponges - some over 50 cm in diameter - and massive basket sponges were common. Fan and lyre gorgonians were conspicuous and common, and sea whip gorgonians up to 2 m long bent in the prevailing current. Branching sponges and small, solitary colonies of hard coral - including Galaxea and Turbinaria - formed patchy aggregations along with larger sponges and gorgonians on the sandy bottom. Coral cutcrops and bommies were rare. Feather stars were often seen clinging to the various types of gorgonian, and tiny sea cucumbers lived among the sponges. Fish of various species could be observed occasionally.

Few changes occurred in the composition of the sessile biota at depths greater than 10 m below MSL. Sponges and gorgonian corals became increasingly sparse as depth increased, and no algae or hard corals grew in this region.

An area of seabed off the south-western corner of Catalina Island was quantitatively surveyed. This site was relatively poor in species richness and diversity. There was very little solid substrata, neither coral rubble or rock, on the gently sloping, sandy seabed. Seaweed of various species was plentiful, and small sponges, ascidians and other invertebrates occurred in low numbers. Hard corals were uncommon and small.

The seabed around Old Man Rock was surveyed at two sites. The north-east site was rocky, with a steep gradient. Silt and fine algae covered most of the rock surface. Small encrusting sponges and small hard corals grew attached to the rock in low densities. Abundance and diversity of the biota was relatively poor.

The south-west site contrasted strongly with the site on the north-east side of Old Man Rock. Rock ridges covered in a profuse and rich community of sessile invertebrates characterised the area. The ridges began in deeper water (5 m below MSL), and consequently the biota was dominated by sponges and gorgonian corals. The size and abundance of the invertebrate fauna at this site was different from the sites surveyed in East Arm. Hard corals recorded during the survey, however, were rare and small. The biota at this site was thus considered to be very different from the generalised community described for North and South Shell Islands.
Comparison of Shell Islands with Other Locations in Darwin Harbour.

Considering that the proposed port will result in the loss of much of the hard seabed communities in the vicinity of the Shell islands, it was decided to undertake a quantitative biological survey to compare a representative area of the Shell Islands hard coral community with other areas in Darwin Harbour which may have similar hard coral communities.

Priority was given to those areas of the Harbour which would be unaffected by the port development, but which are open to general use by the public and licenced collectors of marine biota. While it is recognised that there are rich coral communities around Channel Island, these communities are protected under the National Register and cannot be considered as an alternative site to the Shell Islands for collectors (such as Indo Pacific Marine). Hence, the second survey focused on coral communities outside the Channel Island area, but included one site at Channel Island for reference purposes.

Infra-red aerial photographs of Darwin Harbour at low tide (such as Fig 5.8) were examined to identify potential coral habitat on the basis of comparison with the photographic colour characteristics of known coral communities at the Shell Islands and Channel Island. A total of 24 sites with hard seabed and possible coral growth were identified from the aerial photographs. The location of the sites was documented, and the sites were investigated by a T&W/Acer Vaughan (AV) marine survey crew with the assistance of divers from Indo-Pacific Marine. From the aerial photographs, habitat interpretation, and this investigation, eight of the sites were selected for investigation by CEE marine biologists. Qualitative observations of biota were also made at other locations including Plater Rock, Weed Reef, the Naval Base Breakwater and Fort Hill Wharf piles.

Study Sites and Methods. The study sites are located within the three arms comprising Darwin Harbour, and a site on the south side of North Shell Island. The location of the study sites is shown in Fig 5-9. Quantitative surveying of the corals at the Shell Islands site provided the basis of comparison with the other sites in East Arm, Middle Arm and West Arm. At each location, five 20 m long lines (transects) marked at 1 m intervals were laid along the seabed extending out from approximately 0.5 m AHD. The initial positioning of the transects was made from the boat at the surface, with transects subsequently being pulled tight by the divers. Hence, the actual positioning of the transects was random.

Marine biologists surveyed the biota along the transects by recording the type of organism, seabed character and water depth at each 1 m mark. This method provided data on the diversity, abundance, and species depth range at each site, and will allow numerical comparison of the sites as well as providing sufficient
information on the coral communities at the sites for design of rigorous ecological surveys in the future if required.

It should be noted that the transect method was used specifically to provide information on large corals, for example *Turbinaria* which averages approximately 35 cm diameter at the Shell Islands. Smaller corals (*Favia, Goniopora, Favites, and Fungiids*), and other invertebrates are less likely to be recorded using this method. Other methods such as replicate large quadrats would provide more information on the occurrence of smaller biota. However, a high number of quadrats would be required to collect sufficient information, and quadrats would be difficult to locate in the poor visibility of the Harbour. The replicate transect method allows systematic coverage of large areas of seabed, while providing good comparative data on the composition of the benthic biological assemblages.

The depth records at each site are shown in Figure 5-13, and range and mean depth of the observations at each station is also shown in Figs 5-14a to 5-14f.

**Biota at Survey Sites.** The observations at the sites indicated that there are numerous sites in Darwin Harbour which have rich associations of coral and associated biota. The most widely spread coral was the dish-shaped *Turbinaria* (Plate 1), which was found at all sites with coral. Other corals commonly found at most sites included *Goniopora, Favia, Favites, and* plate or encrusting corals. The most common plate coral (other than *Turbinaria*) was *Echinophyllia*, other large corals included *Echinopora, Acropora, Galaxea, Porites* and *Symphyllia*.

For the purposes of the EIS, the results of the survey are summarised into *Turbinaria, Goniopora, Favia-like* corals and other plate (or encrusting) forms. The results are presented in Table 5.2 and Figures 5-14a to 5-14f. In the figures, each record of the particular biological group is shown against the corresponding depth at which it was recorded for each site. The depth range and mean depth at each site is also shown.

**Results.** There was a high proportion of substratum which was coral rubble at the Shell Island site, with few large, plate-forming corals (other than *Turbinaria*) being present. However, the rubble provided habitat for a variety of other invertebrates including hydroids, sponges, and soft corals and algae.

Table 5.2 and Figure 5-14a show that *Turbinaria* was most common at the Shell Island where it was mostly found between 3.5 to 4 m below MSL (where most sampling points were concentrated). *Turbinaria* was found at all other sites, and was common at the West Arm site where it was most commonly recorded between 3.7 and 4.7 m below MSL. While other plate corals were dominant at most of the Middle Arm sites, *Turbinaria* was recorded and observed lower on the transects, mostly deeper than 5 m below MSL.
Figure 5-14b shows that plate corals were found at most sites. Plate corals included a wide variety of plate and encrusting forms of *Echinophyllia*, *Echinopora*, *Leptoseris*, *Hydnophora*, *Merulina* and various others. *Echinophyllia* was the most widespread plate coral, and was recorded at all sites except those in West Arm. Plate corals were largest and most abundant and diverse at the sites in the main channel of Middle Arm, and were found over most of the depth range of the transects. Plate corals were low in abundance, size and diversity in East Arm, West Arm and at Oyster Rocks in Middle Arm.

Figure 5-14c shows that *Goniopora* was found at all sites, but was most common at Oyster Rocks, south Blackmore Point and North Shell Island. In addition to *Turbinaria*, plate corals and *Goniopora*, over 12 other coral genera were observed at the survey sites. Individually, these corals (*Faviids, Favitids, Fungiids, and distinctive corals such as* *Moseleya, Pectinia* and *Duncanopsammia*) on the transects were numerically insignificant. However, as a "group" they are numerically significant, and show substantial differences between the eight sites. Figure 5-14d shows that the sites in central Middle Arm and the Channel Island site have higher numbers of other hard corals than the East Arm and West Arm sites.

There is a wide variety of sponges in Darwin Harbour ranging from small encrusting forms to large fans and cups and massive forms. Figure 5-14e shows that sponges were found at all sites. Sponges were most common at Whickham Point site in East Arm, where encrusting forms were observed over much of the coral rubble substratum. Fan sponges were generally observed below the coral zone, although this distinct zonation was less obvious at the Shell Islands compared to the Middle Arm and Channel Island sites.

Algae (seaweeds) in Darwin Harbour are generally most common above the coral zone, where coral rubble around the low tide mark is encrusted with various species of red and green algae. The transects were deployed below this level, and therefore few algae were recorded at most sites as shown in Figure 5-14f. However, algae were relatively abundant at the Shell Island site and Oyster Rocks in Middle Arm where the brown seaweed *Dictypteris* was common.

Various other organisms were observed at the study sites, such as anemones, hydroids, tube worms (eg, *Eunice tubifex*), soft corals (*Sarcophyton, Nephthya*), nudibranchs, alcyonarians, bryozoans and ascidians. While these organisms are often strikingly obvious in appearance, they were seldom recorded under the sampling points on the transects, and therefore cannot be considered numerically in this comparison. However, notes of general characteristics of the sites taken during the survey provide useful qualitative backup to the comparisons.
Comparison of Sites. On the basis of the field observations, and data in Table 5.2, and Figures 5-14a to 5-14f, the Shell Islands site was generally similar in character to those at Site 2 (East Arm, north side of Whickham Point), Site 3 at Swires Bluff in West Arm, and at Site 5 at Oyster Rocks (Middle Arm). The seabed at these sites was composed of coral rubble with sand and little exposed rock. There were few plate corals (except *Turbinaria*) at these sites. Encrusting sponges were relatively common at both the East Arm sites, although more numerous at Whickham Point. *Turbinaria* and algae were more abundant at Shell Island, and the diversity and abundance of other invertebrates generally appeared greater at the Shell Islands site. The depth range and mean depth shows that the seabed at the Shell Islands site shelved more gently than all other sites except the Swires Bluff (West Arm) site.

The sites in Middle Arm were generally richer in other species of corals, and the sites in the vicinity of Channel Island (Sites 5, 7, 8 and 9) had the highest frequency of corals which were predominantly plate or encrusting forms of corals such as *Echinopora, Leptoseris, and Galaxea*. At these sites *Turbinaria* was less common, and was generally found deeper than at the East Arm sites.

A hierarchical cluster analysis was carried out to determine if there was a clear relationship between the sites on the basis of the data groupings in Table 5.2 (excluding depth). The results of the analysis are shown in Fig 5-15. The figure shows that the sites in Middle Arm are the most similar to each other (sites 4, 6, 7 and 8). It also shows that, while there is some linkage between the sites at the Shell Islands and Oyster Rocks and Swires Bluff, these and the others are distinct.

Not included in this comparison were the sites at Plater Rocks, Fort Hill Wharf and the Naval Base Breakwater. Plater Rocks was characterised by abundant hard corals like those in Middle Arm. Fort Hill Wharf pilings were characterised by encrusting sponges, bryozoans and ascidians, with no hard corals. The Naval Base Breakwater represented a rocky substratum in the relatively early stages of colonisation by hard corals and associated biota (some 15 years after its construction). Hard coral colonies such as *Turbinaria* and *Acropora* were present, but small in size compared to the other sites.

Hence, while there are similarities in the biota at the various sites around the harbour, distinctions between the sites can be made on the basis of the proportion of particular species present.

Conclusions. There was a high degree of variation in the characteristics of the biological assemblages based on the combinations of coral species at each site, which presumably reflects habitat variation (eg. seabed profile and composition, current regime, ambient water turbidity). In spite of this variation, most species appeared to be represented at most sites. Thus the Shell Islands appear to have a lower abundance and diversity of plate forming hard corals, but a higher
abundance of exposed rubble which provides habitat for a variety of other invertebrate species which may be found in lower abundance at other sites.

In general, the area of hard and rubble seabed between +1 m and -2 m (Chart Datum) provides habitat for a wide variety of corals, other invertebrates and algae. The top of this zone is relatively often exposed at low tides and offers collectors and students an opportunity to fossick among a wide variety of marine biota without the need for diving.

The Shell, Quarantine and Catalina Islands are particularly convenient in this respect because they have a relatively large area of habitat between +1 m and -2 m (Chart Datum) which is readily accessible from the Quarantine Island boat ramp. However similar habitat may be found elsewhere in the harbour (e.g. Oyster Rocks, Whickham Point, Blackmore Point).

**Marine Mammals**

Little is known about the importance of Darwin Harbour for marine mammals. The following notes have been prepared on the basis of discussions with officers of the CCNT and Fisheries Division regarding sightings in the harbour and along other sections of the Territory coastline.

**Dolphins and Whales.** Whales and dolphins generally spend most of their lives in the open ocean; however, dolphins are occasionally sighted in Darwin Harbour. It is most likely that the animals sighted within Darwin Harbour are simply transiting.

**Dugongs.** Dugongs are herbivorous marine mammals. While they are widely distributed, the major remaining populations are all within Australian waters.

A 1983 aerial survey detected Dugongs in Darwin Harbour at densities of 1 to 10 animals per one hundred square kilometres. These numbers are considered to represent low to moderately high densities (Conservation Commission of Northern Territory, in press).

Dugongs feed almost exclusively on seagrasses and consequently are most commonly found in shallow coastal waters where extensive seagrass beds occur. However, they also do feed on algae on occasions, particularly following cyclones when damage to seagrass beds occurs (B Barker-Hudson, pers comm). The moderately high dugong densities in the harbour suggest the presence of significant seagrass beds (CCNT, in press). Likely locations of seagrass beds according to the CCNT include off Mandorah, and outside Darwin Harbour at Casuarina Beach and Fannie Bay.
Dugongs have been observed on the reef near the Channel Island bridge during the dry season, where they were believed to have been grazing on algae (M Mitchie, pers comm).

Marine Reptiles

Turtles. Several species of turtles have been recorded from waters of Darwin Harbour, including Green, Flatback and Hawksbill turtles. Immature Green turtles are most likely to be sighted while feeding on algal turf within the harbour, particularly around Mandorah. Flatback turtles are known to breed occasionally at Channel Island and Mica Beach in Darwin Harbour; however, there are no records of turtle breeding on North Shell Island (M Guinea, pers comm).

Crocodiles. Saltwater crocodiles inhabit the tidal rivers and open water of Darwin Harbour. The Conservation Commission of the Northern Territory maintains a crocodile management programme, which involves removing potential "problem" crocodiles from popular waterways.

Sea Snakes. Various species of sea snakes are common around the mangroves, mudflats and open waters of Darwin Harbour.

5.3.2 Environmental Effects

This section reviews the environmental effects of the construction and operation of the proposed port on the marine biological environment.

Construction Phase

Mangroves and Soft Seabed Communities. Construction of Stage 1 of the proposed port will directly result in the loss of a relatively small area of mangroves, amounting to only approximately 8 ha. No further mangrove removal is implied for the development covered by this EIS. This area represents only about 0.04 per cent of the total 20 000 ha area of mangroves in Darwin Harbour (Ecosystems 1993). It is recognised that the environmental value of mangroves cannot be quantified solely on an areal basis without reference to the structure and productivity of mangroves and associated fauna. Therefore, as about 30 per cent of these mangrove areas consist of low productivity zones such as salt flats and bare mud resulting from cyclone damage, it may be concluded that the loss of these relatively small areas of mangroves would have no detectable effect on the overall diversity or productivity of mangroves in Darwin Harbour.

As discussed earlier, the modified current regime in East Arm resulting from the Stage 1 construction and dredging works will result in some redistribution of sediments in East Arm. The area designated for a possible future bulk cargo rail
loop is expected to progressively fill in with fine sediments, eventually leading to the creation of an enlarged mangrove zone. This seaward progression of the mangroves onto the newly-created shallows can be expected to result in the loss of some existing mangroves on the western shore of Quarantine Island as the surface of the sediments rises. It is not possible at this stage to predict whether the redistribution of sediments in East Arm "upstream" from the new port will result in any changes in mangrove distribution, although any such changes are unlikely to be significant in the context of the overall harbour.

**Pelagic Biota.** Construction of the port will have a relatively short term effect on pelagic biota. Port construction activities and increased turbidity may discourage pelagic fish from entering the port area. However, this effect is likely to last only for the period of construction. Large pelagic species (e.g., great trevally, jewfish and queenfish) have been observed around the existing port, and the existing Darwin port area is a popular fishing location.

**Plankton.** Planktonic biota may be affected by increased turbidity during the construction period. A small proportion of the plankton may be more directly affected by entrainment by the dredge. However, due to the regular and large tidal exchange of plankton with the adjacent Beagle Gulf, impacts on plankton will be localised and relatively short term.

**Benthic Biota.** The construction of the port will have major direct and indirect effects on benthic (bottom-dwelling) biota.

Construction will directly affect all those seabed habitats which are dredged or filled. The port relocation will involve filling the intertidal and shallow subtidal area extending from North Shell Island to Quarantine Island, and the dredging of the rubble and soft seabed between North and South Shell Islands and extending towards Quarantine Island. The seabed existing on the north side of South Shell Island will be removed. As discussed above, the marine biological communities in this area comprise a diverse assemblage of hard and soft seabed biota.

The individual biological taxa presently found in the affected areas are likely to be represented at other hard and soft seabed habitats at other locations in Darwin Harbour (e.g., Middle Arm). However, most of the particular biological associations at North Shell and South Shell Islands will be lost as a result of the construction of the Port.

The construction of the port will create additional hard substratum such as concrete or sheetpiles walls and some rock armouring which will provide habitat for some species. However, it is unlikely that the vertical, shaded walls of the wharves will be suitable for hard coral settlement, but will be colonised by encrusting sponges, some soft corals and bryozoans similar to those on the piles at the existing Fort.
Hill wharf. The rock armour walls are located in sheltered areas and are therefore likely to be subject to silt loads, and will be unsuitable for hard coral colonisation and growth. Hence it is most unlikely that the biological associations presently found in the areas of reclamation and dredging will be re-established.

Construction and the subsequent redistribution of sediments upstream from the port will have a more widespread, indirect effect on benthic biota due to increases in turbidity and sediment loads. As the distribution of many species appears to already be limited by turbidity and blanketing by sediment, these effects could be significant for the hard seabed biota closest to the new port, such as communities at South Shell Island and Old Man Rock. The degree and extent of these effects cannot be defined at this stage, as the nature of the dredging and marine construction techniques have yet to be determined, and it is not possible to accurately predict the extent or duration of increases in suspended sediment concentrations resulting from subsequent reworking of sediments in East Arm. As discussed later, monitoring of biota should be undertaken to assess these impacts and establish the need for any additional measures to minimise construction impacts.

**Marine Mammals and Reptiles.** Construction of the port will have a short term effect on marine mammals and reptiles in the vicinity of the port relocation. Construction activities and increased turbidity may discourage marine mammals and reptiles from entering the area.

**Operational Phase**

The effects of the operational phase on the marine environment may be considered in terms of: (1) increased human and shipping activity; (2) ongoing physical changes due to the reconfiguration of the major channels and barriers to water movement; and (3) the potential for discharges of toxic materials as the result of normal or abnormal port activities.

Increased human and shipping activity in East Arm will affect all aspects of its estuarine environment to some extent. Some biota will colonise the artificial substrata of the wharf structures, but this will tend to be limited to encrusting, hardy species. Plankton will be relatively unaffected, although changes to the water currents and surrounding habitats may alter the proportion of locally derived species. Fish will be affected by the change in habitat. The loss of reef habitat and prey species may reduce the numbers of predatory species such as coral trout, cod, jewfish and so on. Marine mammals and reptiles will tend to avoid the activity in the area.

Potential spills from the anticipated increase in volume and diversity of imported material and the possibility of fuel spillages, together with the local effects of ships' antifouling paints will continue to have potential impact on marine biota for the life
of the port. Proper management of port related activities will minimise the potential for marine environmental damage from these sources. However, there are currently no restrictions over the use and handling of toxic antifouling paints (including tributyl tin formulations) in the Territory.

The predicted progressive infilling of the zone to the north of the port with sediment will result in the creation of a relatively large area of sandfly (biting midge) habitat immediately adjacent to the port. Mudflats and mangrove areas with elevations in the upper neap tide zone (between 3.1 to 5.1 m above Chart Datum) are the main breeding areas for *C. ornatus*, which is the predominant biting midge in the Darwin region (P Whelan, pers comm). Midges are generally most active between 6.00 and 8.00 am and from 6.30 to 8.00 pm, and can be expected to represent a significant nuisance for port personnel (and construction workers).

While a shipping accident in the port area is most unlikely to occur, such an event would have the potential to release bunker oil and/or cargoes into East Arm, with adverse effects on marine life and birds. Hydraulic modelling carried out by Acer Vaughan/Patterson Britton for T&W has been used to assist in selecting the port layout and has predicted peak current velocities of 1.8 m/s in the vicinity of the berths and an eddy in the lee of South Shell Island on the flood tide. As noted in the Master Plan Report, navigation simulations have yet to be carried out by the designers for the proposed port. These will be used to determine whether conditions will be acceptable for berthing and unberthing of vessels under all tidal conditions and if necessary what provisions or controls need to be introduced to the marine-side operations.

It is unlikely that increased shipping will introduce new "problem" species to Darwin Harbour through the release of larvae with bilge water. Tropical species are generally more widespread throughout the world’s tropical regions with little apparent endemism of common species. The Port of Darwin’s large exchange and long history of sea trade with other Asian ports means that the port expansion does not significantly increase the risk of a new species being introduced.

As discussed earlier, mathematical modelling has predicted changes in the physical configuration of "upstream" areas of East Arm, resulting from modified tidal flows as a consequence of the port and dredging works. The changes to mudflats and sand banks may take ten years or more to equilibrate, and can be expected to affect mangroves, soft seabed communities and hard seabed communities by erosion in some areas and sedimentation in others.

5.4 VISUAL AND ACOUSTIC ENVIRONMENT

Visual and acoustic factors are considered together as they both contribute to the aesthetic character of the study area.
5.4.1 Existing Conditions

Landscape Character

The predominant landscape elements of East Arm are the water, the fringing mangroves and extensive areas of tidal mud flats (at low tide). There are few vantage points, apart from on the harbour itself, which provide clear views over the proposed port area. When viewed from the Stokes Hill area, the only features which stand out from the background are the low relief of Quarantine Island (maximum elevation 24 m), the yellow beach on North Shell Island (at low tide) and the grey form of the Northern Cement Plant on Quarantine Island.

Noise Levels

No noise surveys have been conducted in the area of the proposed port. However, the existing acoustic situation is simple, with the Northern Cement Plant and associated truck traffic being the only significant noise source which intrudes on an otherwise low background noise environment.

5.4.2 Environmental Effects

This section reviews the environmental effects of the construction and operation of the proposed port in terms of the visual and acoustic environment.

Construction Phase

The most prominent visual signs of the construction activity, as viewed from vantage points in the city area and from boats on East Arm, will be the removal of vegetation and earthworks on Quarantine Island, and the construction of bunds to form the port area. These will be low in elevation however and will not be a significant visual intrusion.

The main source of noise during construction of the port will be earthmoving equipment and heavy vehicles used to excavate material from Quarantine Island and transport it to the port site, and any pile driving which may be required. As most of the material to be excavated is rippable, limited blasting is anticipated. The remoteness of the site from residential areas will generally ensure that construction of the port does not cause noise problems.

Operational Phase

The most visually-prominent features of the operating port will be the presence of vessels, container crane and containers stacked on the hardstand. Most observers are likely to consider the port as a matter of interest, and an elevated viewing point
on the edge of the port is provided as part of the project to allow interested members of the community to view the developing site. Noise generated by port operations will generally be limited to engine noise from ships, trains, fork lift trucks, heavy vehicles, conveyor systems, and the handling of general cargoes. None of these should be perceptible in any existing residential areas.

5.5 HISTORIC AND ARCHAEOLOGICAL FACTORS

This section reviews the results of two independent investigations of archaeological and historic features within the study area, and other relevant information.

5.5.1 Existing Conditions

In order to enable thorough surveys of Quarantine Island to be undertaken, particularly in relation to the archaeological investigation, it was considered necessary to conduct a controlled burn to clear tall grasses. This burn was conducted in early May 1993 by NT Fire Services following receipt of approval from the CCNT. It should be noted for the benefit of readers who are not familiar with Territory land management practices that a significant proportion of bushland in the Territory is deliberately burnt each dry season, and Quarantine Island is no exception.

Archaeological Sites

The report on the Aboriginal Archaeological Investigation, which was conducted by Mr Ken Mulvaney in May 1993, is reproduced in Appendix G.

Despite extensive modification to Quarantine Island as a result of its use for a quarantine station and as a WWII base in the 1940s, which involved the destruction of some archaeological features, the study positively identified the following features associated with earlier Aboriginal occupation of the site:

- an extensive shell midden (over 90 m in length) in the vicinity of the existing (Catalina) boat ramp;
- a sparse shell "scatter" just above the high tide mark, immediately west of the Northern Cement property;
- a shell midden, together with two lumps of quartz each of which appears to have a single flake scar, on the northern tip of Catalina Island; and
- two isolated artefacts (flaked stone points) near the higher sections of Quarantine Island.
In addition, a number of shell deposits and "scatters" were observed adjacent to some of the WW II sites, which has most probably resulted from use of shell material from middens (probably located elsewhere) for construction purposes. The locations of these features are shown in Fig 5-16.

Of the three confirmed Aboriginal shell middens, the large midden near the Catalina ramp was judged to be of the greatest significance, and its potential research value to be high, although other similar sites have been documented along the Darwin Harbour coast line. The midden was judged to relate to Aboriginal use of the area of the order of 1 000 years ago and it is likely that it contains stone artefacts and other features which would contribute to an understanding of prehistoric occupation of the area. The other two middens are relatively small.

The stone artefacts found on Quarantine Island are in disturbed areas and were judged to be of uncertain antiquity and/or origin; therefore, they may be of greater scientific value if removed from the site for study (subject to the provisions of the Heritage Conservation Act 1991).

Sites of Significance to Aboriginal People

T&W applied to and obtained from the Aboriginal Areas Protection Authority (AAPA) an Authority Certificate giving clearance for the 1992 port concept plan. As a result of revised arrangements embodied in the Masterplan are negotiating with AAPA on some areas of conflict. In principle AAPA have indicated that Catalina Island and the associated sandbar are of cultural significance and need to be protected from impact by the proposed works.

Historic Features

Quarantine Island History. A heritage assessment of Quarantine Island was carried out by Mr Peter Dermoudy as part of the EIS investigations. His report is reproduced in Appendix H while the main points are summarised below.

European occupation of the relatively remote Quarantine Island commenced in 1931 with the establishment of a quarantine station. The Allied Intelligence Bureau established a base on the island in December 1942 for a range of intelligence and subversive/incursive operations, under the "cover name" of the Lugger Maintenance Section (LMS). Australian and allied nationals were involved in these clandestine operations, many of which are only now coming to light. A flying boat base was developed in 1942/43 for use by both the US Navy and the RAAF. Anti-aircraft positions were also established on the island.

Following the cessation of hostilities, most of the wartime facilities were sold, and the quarantine station recommissioned. The quarantine station subsequently
served as a receival point for refugees (mainly "boat people" from Asian nations) and as a detention centre for crew members of seized foreign fishing vessels. The quarantine station was handed over to the NT Government by the Commonwealth in 1981.

The Dermoudy report identifies 32 sites identifiable as WW II military sites and one (No 24) as having been associated with the quarantine station (Fig 5-17). Virtually all relics formerly associated with the quarantine station itself were apparently destroyed and/or dispersed in 1990.

The report concludes that all of the sites identified in Fig 5-17 have heritage values, but that those contained within the area shown in the figure must be considered as being of high significance in terms of a range of Criteria for the Register of the National Estate. The report indicates that the LMS relics and the area which contains them (Fig 5-17) are of National and International significance, and that their heritage value can be expected to increase with time.

This assessment is reinforced by two news items which appeared in the "World News" section of the Melbourne Age newspaper on 16 and 27 September 1993, relating commando raids launched from the LMS base (reproduced in Appendix I). These stories related to: (1) a re-enactment, by Australian and Singaporean personnel, on the fiftieth anniversary of the successful commando raid on Japanese shipping in Singapore Harbour; and (2) a memorial service for 10 commandos who were captured and executed during a subsequent raid on Singapore Harbour.

The only formal heritage listings of European sites on Quarantine Island is currently that of the National Trust of Australia (NT) and the CCNT's Coastal Resources Atlas, neither of which provides any legal protection for the relics.

**Historic Wrecks.** There are a number of ship and aircraft wrecks in Darwin Harbour, which have historic value and also serve as artificial reefs. A publication prepared by the Department of Primary Industry and Fisheries (DPIF), "Darwin's Artificial Reefs", provides brief descriptions of the wrecks and lists their coordinates. The locations of wrecks in the vicinity of the proposed port are shown in Fig 5-10.

The wrecks include a number of Catalina flying boats lost during WW II (three during the Japanese air raids in 1942 and another four in subsequent accidents). Of these, one is known to be located within the proposed port area and another is located at the edge of the proposed dredge basin. Both are the subject of organised dives by both commercial and amateur SCUBA diving groups. Information on these Catalina wrecks, as supplied in the DPIF publication, are as follows:

| Draft EIS | Darwin Port Expansion | East Arm | - 91 - | Acer Vaughan/Consulting Environmental Engineers (AV/532) |
• Catalina (1) is located approximately 700 m east northeast of North Shell Island at a depth of 12 m (co-ordinates 12 deg 29.45'S 130 deg 53.5' E); and

• Catalina (2) is located approximately 600 m east southeast of South Shell Island at a depth of 12 m (co-ordinates 12 deg 29.9'S 130 deg 53.35' E).

The Heritage Unit of CCNT has confirmed that while the Catalina wrecks are of some historic interest, none of them has been formally assessed by CCNT to date, nor do they have a protected status.

5.5.2 Environmental Effects

Construction Phase

Archaeological Sites: The proposed Stage B as depicted in Figure 3-9, will require the removal of the shell middens identified in 5.5.1 above. The Proponent proposes therefore that, as recommended by Mr Mulvaney in this event, these middens be assessed in detail prior to construction so as to record their pre-historical significance.

Sites of Significance to Aboriginal People: The Proponent will comply with the requirement of the final Authority Certificate in respect of the Catalina Island sacred site.

Historical Site: At this stage of the LMS base has not been listed on the Register of Heritage Places. In accordance with the NT Heritage Act interested parties can submit a proposal to the Heritage Advisory Council for the site to be listed. At the time of writing, it is understood that a process has been set in motion to address this matter. After due process the Advisory Council will make recommendations to the Minister for his decision. If the site is then listed, gazetting and preparation of a Conservation Management Plan will follow. In the event that the site is listed the Proponent will ensure that the gazetted area is secured and protected in accordance with the requirements of the Conservation Management Plan.

Historical Wrecks: Catalina flying boat wrecks at two locations will be effected by the works. At the time of writing discussions were ongoing between the Proponent and the Australian Navy and the Aviation Historical Society in order to determine the most appropriate means of dealing with the wrecks. The Proponent undertakes, to assist in relocating/salvaging the wrecks in accordance with the agreed resolutions of these discussions.

Operational Phase: No implications over and above those discussed above for construction.
5.6 REGIONAL PLANNING AND SOCIO-ECONOMIC CONSIDERATIONS

The proposed port relocation has important implications for regional planning, development in the Darwin region and for a number of existing activities in the harbour.

5.6.1 Existing Conditions

As noted earlier, there are no feasible alternative sites for the proposed port relocation. Therefore strategic plans for Darwin's future growth have for many years provided for the eventual transfer of port operations from the Stokes Hill/Fort Hill area to the proposed East Arm location. This section briefly reviews the proposal in the context of future growth strategies for Darwin and its implications for the transport network and urban infrastructure.

Regional Planning Strategy

The pattern of future development of Darwin has been influenced by a range of (sometimes conflicting) factors including: (1) the location of the city centre on the tip of a relatively narrow peninsula; (2) the presence of the airport and large areas of Commonwealth military land immediately to the east of the city; (3) the availability of land which is elevated above predicted cyclonic surge levels; (4) the need to minimise nuisance and potential health risks associated with biting insects; (5) a strong preference by residents to live close to the harbour; and (6) the location of existing and proposed port facilities.

Planning studies over the past decade have tended to support a long-term development strategy involving the progressive establishment of urban areas around the harbour towards the Cox Peninsula. The development of the town of Palmerston, the expansion of industrial and employment-generating activities in the East Arm/Berrimah area (including the Trade Development Zone (TDZ) and the Northern Cement plant), the identification of the proposed East Arm port site, and the construction of the Channel Island Power Station and its access road are all consistent with this strategy. However, it is clear that most development pressure in the short to medium term will be focused on the area around East Arm, south of the Stuart Highway and extending between the Darwin Central Business District and Palmerston (generally known as "Darwin South").

The Department of Lands Housing and Local Government released a Preliminary Land Use Concept for Darwin South in September 1992, as the first step in establishing a plan and a strategy for the orderly development of this area. This concept envisages a major port complex located off Quarantine Island in East Arm (the site of the port proposal which is the subject of this EIS). The concept plan provides for the bulk of the land between the East Arm port and the Stuart Highway...
to be reserved for industrial and Government use (including the TDZ), and a rail corridor for the long-awaited southern rail link.

The NT Government has yet to make a decision on whether to proceed with the Darwin South concept, and if so, the nature and staging of the development (a series of investigations into various elements of the concept is currently under way). However, as noted earlier, the Government has made a firm commitment to develop the new port in East Arm. Therefore, future planning of Darwin South will have to be "dovetailed" with development plans for the port.

Existing Land Ownership

Northern Cement Limited’s Quarantine Island plant is situated mainly on leased public land, together with a small section of freehold land. The Paspaley Pearling Company has freehold title over a small section of land to the east of the existing boat ramp, which is used as a base for servicing its pearl culture operations in East Arm.

The Northern Cement plant was originally located on Quarantine Island with the proposed port in mind, and the land on which it is situated will be incorporated into the new port development. The Paspaley site will not impose any immediate constraint on Stage 1 of the proposed port development; however, as noted in the Master Plan, "long term use of this parcel of land will need to be resolved with the owners to ensure that it does not impose any constraint to the successful development of the port".

Commercial Aquaculture Operations

Two commercial pearl culture operations are conducted in areas of East Arm leased from the NT Government by the Paspaley Pearling Company Pty Ltd and South Sea Pearling Pty Ltd, respectively. The 15 year Paspaley lease has been in force since 1983 over an area of 335.5 ha on the southern side of East Arm, which takes in a 2.5 km long section of the main channel and extends about half-way up two adjacent mangrove creeks. The nearest boundary of the Paspaley lease is approximately 750 m from the swing basin of the proposed port, and most of this distance is occupied by the shallows which extend in a generally southeasterly direction from near South Shell Island. As the South Sea Pearling lease is located considerably further (about 4 km "upstream") from the proposed port, this discussion focuses on the Paspaley Pearling operation in East Arm.

Paspaley Pearling now uses its East Arm lease for "resting" juvenile oysters (120 to 180 mm in size) which have been collected from the sea near Broome and seeded by technicians to induce pearl production, before they are transferred to the Company’s growing-out leases on the Coburg Peninsula. This resting period has
been found to be necessary to avoid the high mortality which occurs if the recently-seeded oysters are transferred directly to the growing-out leases. Approximately 24,000 young oysters are rested in East Arm each year between November and the following July. They are held in plastic-covered wire baskets which are suspended from a system of floating long-lines moored to the seabed. As pearls are not harvested until between 30 and 36 months after seeding, no pearls are present in the oysters in East Arm.

The Company believes that the success of the resting stage can be attributed to the abundant supply of (particulate) food in East Arm for the filter-feeding oysters, and that the colour (and hence the quality and value) of the pearls is related to the nutrition of the oysters.

Indo Pacific Marine

As noted earlier, Indo Pacific Marine operates innovative and impressive displays of local marine life in an aquarium adjacent to the Stokes Hill Wharf. The aquaria are designed and maintained to enable a wide variety of marine plants and animals to flourish in associations which closely resemble the "real life" communities on reefs in the harbour. The display is a popular tourist attraction, as it enables visitors to observe, under ideal viewing conditions, literally hundreds of different species of marine organisms living and feeding together.

The proprietors have a permit from the Fisheries Division to collect marine organisms to establish and restock the displays as required. Their principal collecting area is the reef area which extends between Quarantine and North Shell islands, as this area supports very diverse marine life and can be readily accessed on foot at low tides. All of this reef area will eventually be covered by the proposed port development.

Recreational Use of the Harbour

Darwin Harbour is a popular location for recreational fishing and boating, while a number of clubs and commercial operations conduct SCUBA dives at a number of locations.

The harbour supports a range of fish and crustacean of interest to recreational fishermen (it has been closed to commercial fishing except for some limited gill netting). The most popular fishing areas in East Arm are the mangrove creeks, such as Hudsons, Blesers and Reicharts creeks, where mud crabs and barramundi are the main target, and the reef and channel areas in the vicinity of the Shell islands, where pelagic and reef fish are caught. Other reef areas, such as Old Man rock and the area to the west of South Shell Island, together with a number of
artificial reefs comprising sunken Catalinas and boats, are also common fishing sites.

The Quarantine Island boat ramp represents an important launching point for recreational boating trips on the harbour, although many people find the boat ramps at Dinah Beach and Fannie Bay (in the outer harbour) and at Channel Island and the Elizabeth River more convenient. The final choice of boat ramp for individuals depends on a number of factors including their home base location, their destination within the harbour, and wind wave and tidal conditions.

SCUBA diving in East Arm is hampered by the often poor visibility (due to suspended solids resulting from storm runoff and resuspension of fine sediments by tidal currents) and by concerns over salt water crocodiles. However, as discussed earlier, there are a number of reef areas in East Arm, particularly in the vicinity of South Shell Island and along the channel which separates it from North Shell Island, which support species-rich and attractive coral communities. Organised SCUBA dives are regularly arranged to explore these reefs and several wrecks in the area during periods of better-than-average visibility.

The ready accessibility of North Shell Island from the Quarantine Island boat ramp and its beaches make it an attractive picnic site for boating enthusiasts (as noted earlier an apparent reduction in the number of birds roosting on this island has been attributed to increased visitation).

5.6.2 Environmental Effects

This section reviews the environmental effects of the construction and operation of the proposed port in terms of regional planning and socio-economic considerations.

Construction Phase

The size of the construction workforce and the development schedule for Stage 1 will not be known until tenders for the project have been received and evaluated; nor is such information available for construction of the subsequent stages. However, as the major proportion of the construction work will involve conventional civil and port works, it is likely that the construction and professional workforce will be sourced largely from within the Territory. Therefore, the project should not require any significant influx of personnel or produce any significant additional demands on existing housing, urban infrastructure or community support services.

It is understood that reasonable access to the existing boat ramp on Quarantine Island or an alternative can and will be maintained for the general public during the development of Stage 1 of the port. However, there will be a period during
subsequent development of the shallow berths and their land-backing when public boat launching facilities may not be available at all times during the construction phase. While the lack of a boat ramp will inconvenience some people during this period, this cannot be considered to represent a major impact because: (1) a number of other ramps will be reasonably available; and (2) the Master Plan provides for a new boat ramp, in a more sheltered location.

Indo Pacific Marine will be inconvenienced by the port proposal, from the time when marine construction work commences, because of the loss of their main collection area which is currently accessed on foot. While some areas of the Quarantine Island reef will not be directly affected by Stage 1, indirect effects resulting from increased turbidity can be expected to adversely affect marine biota in these areas (refer to Section 5.3). However, as discussed earlier, it should be possible for Indo Pacific Marine to collect all the material which they require from other locations in the harbour. Additional time and expense will be involved in making collections from these alternative sites, as they are more remote (eg in Middle Arm) and can only be accessed by boat (collection of material from the Channel Island reef is not possible because of its protected status).

Expected increases in suspended solids concentrations in the general vicinity of the two commercial pearling leases could be expected to have some effect on pearl oysters, which rely on filtering microscopic food particles from the water column. It is not possible, on the basis of available information, to predict the extent to which suspended solids concentrations are likely to be increased in the vicinity of the leases, or whether such changes are likely to adversely affect the pearl culture operations.

Operational Phase

The fact that the proposed East Arm Port has been anticipated in planning for many years as an important element of Darwin’s future infrastructure means that its operation is unlikely to have any unexpected effects on the pattern of development of the Darwin region; rather, it represents a key Government initiative to stimulate the NT economy.

The transfer of certain port operations from the existing location to the new port will not in itself have any effect on the overall level of economic activity; however, it will provide a range of significant benefits including:

• creating redevelopment opportunities for the existing port area and adjoining CBD area;

• redirecting heavy truck traffic associated with port operations away from the vicinity of Darwin city centre to the Berrimah industrial zone, with a
consequent reduction in vehicle kilometres travelled, noise, air emissions and safety concerns for people in the Stokes Hill port precinct; and

- stimulating the development and expansion of port-dependent industrial and commercial activities in the TDZ and Berrimah industrial areas.

The expectation that a rail terminal and cargo interchange will be developed later at the East Arm Port, aimed at attracting a significant share of the container traffic which currently passes through ports in the southern and eastern States, has the ability to greatly increase the level of economic activity in Darwin.

The proposal is unlikely to have a significant impact on recreational use of East Arm for fishing, particularly as a new public boat ramp is to be included in the project. While some existing fishing spots will be lost or modified, the port structures should more than compensate for the loss of reef area as a habitat for reef organisms and fish.

Most of the commonly used SCUBA dive sites in East Arm will be lost or significantly modified as a result of the proposal (refer to Section 5.3). However, the rich coral reefs identified in Middle and West Arms of the harbour as part of the investigations for this EIS, will provide other options for such dives.

The ultimate loss of North Shell Island which currently provides one of the few significant firm high tide beach areas in the harbour will reduce the available range of recreational boating activities. However the limited size and fragile nature of the location would limit the potential usage of this facility.
6. ENVIRONMENTAL SAFEGUARDS AND MONITORING

Any proposal of the scale of the proposed East Arm port is bound to have a range of potential environmental impacts; however, many of these can be minimised or avoided through incorporating appropriate environmental safeguards into the design, construction and operational phases of the project. In this context, the term "safeguard" is taken to include any measure which is designed to either totally avoid potential impacts or reduce their magnitude, extent or probability of occurrence.

Monitoring of specific sectors of the environment is often warranted during the construction and/or operational phases to: (1) provide more precise information on the nature of potential impacts which cannot be precisely predicted; (2) ensure that the safeguards are appropriate (experience may show that some are not required, while others may need to be strengthened); and (3) enable the design and construction of subsequent development stages to be refined to further minimise impacts.

This chapter reviews safeguards and monitoring which are considered to be appropriate for the proposed port development.

6.1 ENVIRONMENTAL SAFEGUARDS

The description of the proposed project contained in Chapter 4 is largely based on the Master Plan report (Gutteridge Haskins & Davey 1993). The report notes that "the purpose of the Masterplan is to provide a vision for the ultimate development of the port", and it defines the extent and likely layout of the port at full development. Stage 1 of the port will invite alternative proposals for the form of the wharf structures and thus few confirmed details are currently available on the design or, construction techniques to be employed. Therefore, many of the environmental safeguards identified below as being appropriate for the proposal are, of necessity, "generic" in nature and may need to be refined at a later date when more details of the project become available.

Appropriate safeguards are summarised below first for the construction and then the operational phase of the port.

6.1.1 Construction Phase

Construction of the port will occur in several major stages, presumably with some incremental growth of relatively minor port facilities and port-related industry. Stage 1 is likely to commence in early 1994 and continue construction for 2 years beyond this, no details of likely construction periods are available.
Terrestrial Environment

The Masterplan provides for the removal of essentially all existing terrestrial vegetation from Quarantine Island, and reducing all land above 4.5 m AHD to an essentially level surface, suitable for industrial use. Most of the extracted material will be used for bunds and general fill during construction of the port, while the remainder will be used to raise low-lying sections of the island to the 4.5 m AHD level. Armour rock derived from sources other than Quarantine Island will be extracted from licenced quarries in the Darwin Region, which are required to comply with the conditions of their particular mining lease. Therefore, this potential issue is not considered further in the present EIS.

The objectives and nature of environmental safeguards which are to be applied to the earthworks on Quarantine Island and the stabilisation of disturbed areas pending industrial development are summarised below.

Erosion Control. Water and wind erosion of disturbed areas can lead to soil loss, silting of mangrove areas, increased turbidity and sedimentation in the waters of East Arm, and dust emissions. The Proponent will adopt good construction practices which will ensure erosion impacts are minimised; these will include where appropriate measures such as:

- minimising the extent of disturbed areas to the practical minimum, with progressive rehabilitation of completed areas by topsoil and grassing;
- using water trucks and/or irrigation systems as required to minimise dust emissions and assist in vegetation establishment;
- providing a surface drainage system to divert runoff away from disturbed areas and protect mangroves;
- providing silt traps to minimise off-site sediment discharges;

Mosquito Breeding Sites. Careful attention will be given to the design and maintenance of earthworks and drainage systems to avoid the creation of significant habitat areas for mosquito larvae. The use of larvicides may be required to prevent mosquito breeding in silt traps.

Estuarine Environment

The main safeguards which can be applied to minimise the impacts of construction on the estuarine environment are concerned with reducing suspended solids loads on East Arm by: (1) the adoption of good construction practices in disturbed areas of Quarantine Island; (2) use of a shroud on the cutter/suction head of the
dredge(s) to minimise the loss of fine sediments; (3) reducing the concentration of suspended solids in the dredge return water to East Arm by maintaining adequate detention within the bunded port construction area; (4) maintaining a zone of armour rock on the outer face of the bunds during their construction to minimise erosion of the bunds by currents and wave action. These precautions will be used independently or together to control any emerging concerns identified by the monitoring programme.

Visual and Acoustic Environment

In view of the remoteness of the port site from areas frequented by the public, no special provisions are considered to be required in relation to the appearance of the works during construction.

Noise emissions from heavy earthmoving equipment, such as bulldozers and scrapers, are not expected to be detectable in residential areas, which are about 5 km away. Any blasting which may be required should be designed to meet blast overpressure and vibration guidelines in the nearest residential areas. It is not clear whether construction will involve pile driving, which is a potentially significant source of noise. Should pile driving be undertaken, consideration may need to be given to limiting the period of operation to daylight hours.

Historic and Archaeological Factors

Archaeological Sites: As discussed in Section 5.5.2 the shell middens on Quarantine Island are to be assessed and recorded before removal.

Sites of Significance to Aboriginal People: The Proponent will comply with the requirements of the final Authority Certificate in respect of the Catalina Island sacred site.

Historical Sites: The Proponent will ensure, in the event that protection is conferred under the Heritage Act, that the gazetted area is secured and protected in accordance with the Conservation Management Plan.

Historical Wrecks: The Proponent will assist in relocation/salvaging of the two Catalina wrecks in accordance with recommendations of the Australian Navy/Aviation Historical Society.

Regional Planning and Socio-Economic Environment

Construction of the new port will provide a stimulus for economic activity in the region, although it should not impose any significant strains on the local labour market, community support services or urban infrastructure. Therefore, no specific
measures are anticipated required in this regard.

There will be a period during construction when public access for launching boats will not be available on Quarantine Island. Advice on the period during which boat launching will not be available will be provided to the public.

As noted earlier, a range of measures can be used to minimise the effect of dredging on suspended solids concentrations in East Arm and other sections of the harbour. However Paspaley Pearling personnel have indicated that the pearl culture operations in East Arm may be scaled down, as a precautionary measure, until any effects on the oysters have been established.

6.1.2 Operational Phase

Operations at the new port will initially involve a transfer of existing port activities from the more congested Port Darwin area, adjacent to the CBD, to East Arm where adjoining land uses are also industrial. In the longer term, the new port has the potential to handle substantial increases in cargo traffic, particularly following completion of the rail link to the southern states.

Terrestrial Environment

Normal operations at the port are not expected to have any significant impacts on the surrounding land.

As applies at the existing port, facilities and procedures for handling any potentially hazardous materials will comply with the Association of Australian Port and Marine Authorities standards, while the land transport of such materials must be undertaken in accordance with NT Work Health Authority requirements.

Air quality guidelines have yet to be adopted for the Territory; however, CCNT will assess the air quality implications of all proposals to establish industries in the port area at the planning approval stage. Any necessary emission controls will be based on prevailing National Health and Medical Research Council guidelines and any applicable National Standards.

Estuarine Environment

Any potential risks of shipping accidents during berthing or unberthing manoeuvres will be investigated by carrying out navigation simulations using the predicted current conditions to identify envelopes of difficult or dangerous tide flow situations for specific types of vessels, so that these conditions can be avoided.
The provision of appropriate bunding around storage facilities for bunker oil and potentially toxic chemicals passing through the port will ensure that any spills can be contained and no significant discharges of contaminated runoff to East Arm occur. The storm water drainage system will discharge through a triple interceptor into the berth area. The interceptor will enable oil from vehicles using the port to be collected, while discharge into the strong current zone will maximise the dilution of traces of contaminants in stormwater. No drainage will be permitted to occur to the zone to the north of the port, as this is likely to be progressively infilled with fine sediments and be colonised by mangroves and associated marine fauna.

Measures will be required to minimise the discharge of antifouling paint scrapings from ship repair facilities to East Arm. This can be achieved by providing specific areas equipped with traps for scraping down vessels.

Visual and Acoustic Environment

The relative remoteness of the proposed port and its low profile mean that it will not be visually prominent, unless viewed from Quarantine Island or nearby areas of East Arm. The most visible elements of the port are likely to be vessels in the port area and containers stacked on the hardstand.

Noise emitted from operations at the port is not expected to be detectable in residential areas. Potential noise emissions from industries which propose to locate in the port-related industrial zone will be considered by CCNT at the Planning Permit stage and any the need for any controls or time limitations on operations will be assessed at that time.

Historic and Archaeological Factors

No implications over and above those discussed above for construction.

Regional Planning and Socio-Economic Environment

No specific safeguards are required in relation to the planning and socio-economic implications of the operation of the proposed port, as the effects should be largely positive for the region.

6.2 MONITORING

Monitoring of specific effects is warranted during the construction and/or operation of major projects such as the East Arm Port to: (1) provide more precise information on potential impacts which cannot be precisely predicted; (2) ensure that the safeguards are appropriate (experience may show that some are not required, while others may need to be strengthened); and (3) enable the design...
and construction of subsequent development stages to be refined to further minimise impacts.

The monitoring programme will be undertaken by the proponent developed in consultation with the CCNT.

6.2.1 Construction Phase

Monitoring to be conducted during successive construction stages includes the following:

**Terrestrial Environment.** Regular inspections to CCNT’S satisfaction will be made of areas of Quarantine Island which have been affected by construction activity, focusing on (but not limited to) the following aspects:

- rehabilitation and establishment of groundcover on disturbed areas;
- stormwater diversion and drainage systems;
- silt traps;
- protection of any areas set aside on the basis of their heritage or cultural value.

**Birds.** Monitoring of birds on North Shell Island will be undertaken on a monthly basis prior to and during the construction period to assess the status of the Beach thick-knee (of which only 1,000 birds remain in Australia) and waders in East Arm. The information collected during the monitoring program will provide valuable input for environmental management of future coastal development in East Arm.

**Estuarine Environment.** Environmental monitoring should form an integral part of the management of construction and operational phases of the port relocation. The Commonwealth EPA is presently developing guidelines for offshore dredging and spoil disposal and the CCNT is developing similar guidelines for the NT Coast including Darwin Harbour. Hence, the final details of the monitoring program will be developed in consultation with CCNT. The broad thrust of the monitoring programme is discussed below however.

Monitoring will focus on the extent and intensity of sediment plumes, sedimentation, scouring, and biological effects. Extensive sediment plumes, heavy siltation or detrimental biological effects may indicate the need to consider changes in the construction protocol (eg limiting dredging and discharges of dredge return water to ebb tides, increasing the volume of "settlement ponds" for the dredged material, and silt curtains on the dredge cutter/suction head).
The monitoring will comprise five components:

1. **Aerial surveys.** The present extent of mudflats and turbidity in East Arm and adjacent areas of the harbour will be plotted from aerial photographs taken at appropriate low tide and high tides. These will provide baseline information on conditions prior to construction.

During the early periods of each major phase of dredging and marine construction activity, comparative aerial surveys will be run to monitor the extent and intensity of turbidity plumes.

2. **Bathymetric profiles.** Existing information on the extent of mudflats, depths of sand banks and shapes of channels will be supplemented by accurate bathymetric profiles taken across representative mudflats, sandbanks and channels. The bathymetric profiles will also provide invaluable information on sediment movement patterns for use in determining future dredging programmes and fill sources.

3. **Turbidity measurements.** The extent of turbidity plumes can be plotted from aerial photographs. However, the concentration of the plumes for comparative purposes is best quantified by measurement in the field. Measurements will be taken during peak construction activities at high and low tides. Measurements will be taken over the water depth by submersible turbidity meter. Semi-quantitative measurements such as Secchi disk or Black spot may suffice but will be calibrated during each survey by collection of representative water samples for suspended solids analysis.

4. **Sediment traps.** While net deposition rates of sediment may be small, sediment flux may increase due to construction activities. Increases in sediment flux may be measured using sediment traps positioned at strategic locations around East Arm and at potentially sensitive areas outside East Arm (eg, seagrass beds, mangrove thickets and coral areas).

5. **Biological effects.** The fundamental concern for monitoring is the impacts that construction has on the marine biological assemblages in East Arm and elsewhere in Darwin Harbour. Hence, monitoring of appropriate marine biota will be an essential component of the monitoring programme during construction of the port.

Hard corals are generally considered to be sensitive to sediment loads (Grigg 1970, Johannes 1975), and there is local concern over the effects of the port relocation on corals and associated biota elsewhere in Darwin Harbour. Hence, monitoring of corals will be undertaken during the construction period.
Corals will be monitored at South Shell Island (where they are retained), Old Man Rock, Point Whickam and other selected locations in Darwin Harbour. Monitoring will involve photographing 20 representative individual corals at each site, initially at monthly intervals. Corals will be located by measuring distances along permanently marked transects. Experience shows that, while visibility may be very poor at times, sufficient detail of the corals' condition can be interpreted from photographs taken within a distance of 1 m from each.

Other sensitive biological associations which may be monitored include mangrove associations (McGuiness 1993) and seagrasses. The final details of the monitoring programme will be determined in consultation with CCNT.

Visual and Acoustic Environment. It is unlikely that any monitoring of visual or acoustic factors will be required during the construction phase, unless the techniques to be used for any blasting or pile driving have the potential to cause annoyance in the nearest residential areas.

Historic and Archaeological Factors.

No monitoring is proposed over and above the routine inspections that regulatory authorities (CCNT & AAPA) undertake to ensure concurrence with requirements in respect of protected areas of historical cultural interest.

Regional Planning and Socio-Economic Environment. No project-specific monitoring is necessary during construction in respect of planning and socio-economic factors.

6.2.2 Operational Phase

Terrestrial Environment. The application of current Government controls related to drainage systems, road conditions and the presence of plant or animal pests will suffice for areas of Quarantine Island which have been prepared for industrial use but have yet to be developed.

Estuarine Environment. A monitoring programme will be developed to quantify waste loads on East Arm arising from port operations. The programme will focus on any potentially toxic materials which are used or handled at the port (such as TBT antifouling paints, heavy metals and bunker oil), and involve analysis of discharges and fine sediments in the vicinity of the port.

Visual and Acoustic Environment. No project-specific monitoring should be required in relation to these factors.
Historic and Archaeological Factors.

No monitoring is proposed.

Regional Planning and Socio-Economic Environment. No project-specific monitoring are necessary in respect of planning and socio-economic factors, as the existing planning processes will monitor and respond to the effects of the new port on the demand for port-related and general industrial developments.
7. INFORMATION SOURCES AND COMMUNITY CONSULTATION

This chapter reviews the sources of information used as a basis for preparing the Draft EIS and identifies community organisations consulted during the course of this assignment.

7.1 INFORMATION SOURCES

An EIS Co-ordination Committee was established by CCNT to assist in defining the scope of the EIS, identifying relevant information and generally monitoring the progress of the investigation. The Co-ordination Committee, which comprised senior personnel from a number of Government authorities including CCNT, T&W (including the Darwin Port Authority) and the Department of Lands Housing and Local Government together with representatives of consultant team, met on three occasions during the project.

The report on the Darwin South Baseline Studies Review (Dames & Moore 1992), contained an extensive list of references on environmental conditions in the study area, and represented a useful "check list" for purposes of the EIS. Members of the EIS study team have had extensive involvement in investigations into physical and biological processes, and heritage sites in Darwin Harbour and its environs since 1974.

7.2 PUBLIC INVOLVEMENT AND CONSULTATION

During the initial stage of the EIS process, contact was established with a range of organisations having particular interests in the implications of the port relocation proposal. The main purposes of these preliminary consultations were to: (1) provide these organisations with an initial overview of the nature of the proposal and the time schedule for preparation of the EIS; (2) obtain information on any specific requirements or concerns which should be taken into account in preparing the EIS; and (3) identify additional sources of relevant data (including information held by community groups and their members. Organisations contacted included the following:

Government Departments and Organisations
- Conservation Commission of the Northern Territory;
- Department of Lands, Housing and Local Government;
- Aboriginal Areas Protection Authority;
- Darwin Port Authority;
- Department of Primary Industry and Fisheries;
- Bureau of Meteorology;
- NT Museum;
Department of Health and Community Services;
CSIRO Division of Tropical Ecology
Northern Territory University

Commerce, Industry and Tourism
- Northern Cement;
- Paspaley Pearling;
- Coral Divers; and
- Indo Pacific Marine.

Community Groups
- The Environment Centre NT Inc;
- National Trust of Australia (NT);
- Darwin Amateur Fishing Club;
- SCUBA diving clubs; and
- Local naturalists (including bird observers).
REFERENCES


CCNT (in press). Coastal resources atlas of the Northern Territory. Conservation Commission of the Northern Territory.


Draft EIS - Darwin Port Expansion East Arm - 110 - Acer Vaughan/ Consulting Environmental Engineers (AV/532)


Seminiuk, V (1985). Mangrove environments of Port Darwin, Northern Territory: the


Plate 1. Large vase-shaped hard coral *Turbinaria*. A white sea-whip coral is visible in the background.

Plate 2. Large, bowl-shaped sponge. An orange, irregularly branched sponge and a green-brown globular sponge can be seen in the lower left. Soft corals of two shades of pink can be seen above.

Plate 3. The colourful nudibranch, or sea-slug, *Ceratosoma trilobatum*.

Plate 4. Angel fish swimming over *Turbinaria* plate coral. Note hydroids (right) and finger sponge (left) in foreground.
Plate 5. A clown fish (*Amphiprion sp.*) among *Turbinaria* plate coral (left), pale fan sponges (right) and the hard coral *Goniopora* with tentacles extended (centre foreground).

Plate 6. Mixed assemblage of sessile biota, including a hydroid-encrusted tube of the worm *Eunice tubifex*, feathery stinging hydroids, a Faviid hard coral, and the extended feeding tentacles of the hard coral *Goniopora*.

Plate 7. Typical deep water fauna, including large fan sponges (purple, yellow and white), branched sponges (red and purple) and the fleshy tentacles of a hard coral. Note bare sand.

Plate 8. The common hard coral *Turbinaria* (yellow-green) and large pink fan sponges in deeper water. Note bare sand.
Plate 9. Orange gorgonian soft coral with white feeding tentacles extended.

Plate 10. The soft coral *Nephthea*. Note fine, feathery stinging hydroids in right of picture.


Plate 12. Typical deep-water assemblage, including orange gorgonian soft corals, large grey fan sponges and fleshy ascidian (at base of centre gorgonian).

*All photos by Scott Chidgey, Consulting Environmental Engineers.*
TABLES
Table 2.1 Existing and Potential Demands on Port Facilities

Projected Freight Volumes passing through the Port of Darwin

Note: excludes cargo handled by Perkins and other operators not using Darwin Port Authority facilities.

<table>
<thead>
<tr>
<th>IMPORT - Mass Tonnes</th>
<th>Actual Tonnage 91/92</th>
<th>Projected Tonnage 93/94</th>
<th>94/95</th>
<th>95/96</th>
<th>96/97</th>
<th>97/98</th>
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<tr>
<td>Petroleum Products</td>
<td>368,219</td>
<td>422,185</td>
<td>490,438</td>
<td>496,972</td>
<td>503,604</td>
<td>510,336</td>
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<td>Motor Spirit</td>
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<td>151,728</td>
<td>151,728</td>
<td>151,728</td>
<td>151,728</td>
<td>151,728</td>
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<tr>
<td>Fuel Oils</td>
<td>72,180</td>
<td>86,621</td>
<td>86,621</td>
<td>86,621</td>
<td>86,621</td>
<td>86,621</td>
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<tr>
<td>Aviation Gas</td>
<td>54,553</td>
<td>115,669</td>
<td>115,669</td>
<td>115,669</td>
<td>115,669</td>
<td>115,669</td>
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<tr>
<td>Distillates</td>
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<td>50,836</td>
<td>50,836</td>
<td>50,836</td>
<td>50,836</td>
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<td>Other Petroleum</td>
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<td>24,597</td>
<td>24,597</td>
<td>24,597</td>
<td>24,597</td>
<td>24,597</td>
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<tr>
<td>Cement Clinker</td>
<td>66,000</td>
<td>41,100</td>
<td>66,000</td>
<td>70,000</td>
<td>75,000</td>
<td>77,000</td>
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<td>Passenger Motor Cars</td>
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<tr>
<td>Other</td>
<td>51,037</td>
<td>34,932</td>
<td>53,456</td>
<td>54,528</td>
<td>55,076</td>
<td>55,632</td>
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<tr>
<td>Timber</td>
<td>581</td>
<td>1,073</td>
<td>1,074</td>
<td>1,074</td>
<td>1,074</td>
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<tr>
<td>TOTAL</td>
<td>488,375</td>
<td>509,893</td>
<td>614,571</td>
<td>634,661</td>
<td>653,873</td>
<td>673,194</td>
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<table>
<thead>
<tr>
<th>EXPORT - Mass Tonnes</th>
<th>Actual Tonnage 91/92</th>
<th>Projected Tonnage 93/94</th>
<th>94/95</th>
<th>95/96</th>
<th>96/97</th>
<th>97/98</th>
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<td>Zinc Ore</td>
<td>92,983</td>
<td>68,608</td>
<td>68,608</td>
<td>76,739</td>
<td>84,699</td>
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<td>Lead Ore</td>
<td>29,847</td>
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<td>26,842</td>
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<td>28,847</td>
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<td>Cattle</td>
<td>29,451</td>
<td>49,789</td>
<td>74,694</td>
<td>89,620</td>
<td>107,544</td>
<td>129,063</td>
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<td>Frozen Beef</td>
<td>12,504</td>
<td>5,651</td>
<td>5,651</td>
<td>5,651</td>
<td>5,651</td>
<td>5,651</td>
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<tr>
<td>Lime/Fabricated Cost Mat</td>
<td>7,139</td>
<td>5,463</td>
<td>5,463</td>
<td>5,463</td>
<td>5,463</td>
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<tr>
<td>Uranium</td>
<td>4,195</td>
<td>1,394</td>
<td>2,000</td>
<td>2,000</td>
<td>3,000</td>
<td>4,000</td>
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<tr>
<td>Hay, Chaff &amp; Fodder</td>
<td>2,384</td>
<td>5,325</td>
<td>7,988</td>
<td>9,585</td>
<td>11,502</td>
<td>13,802</td>
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<tr>
<td>Empty Used Containers</td>
<td>2,144</td>
<td>2,069</td>
<td>2,100</td>
<td>2,200</td>
<td>2,400</td>
<td>2,500</td>
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<tr>
<td>Other</td>
<td>37,852</td>
<td>20,728</td>
<td>61,928</td>
<td>61,928</td>
<td>61,928</td>
<td>61,928</td>
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<tr>
<td>TOTAL</td>
<td>218,531</td>
<td>185,669</td>
<td>254,763</td>
<td>271,979</td>
<td>301,522</td>
<td>335,114</td>
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</table>

Projected Vessel Visit statistics for the Port of Darwin

Note: excludes vessels not using Darwin Port Authority facilities.

<table>
<thead>
<tr>
<th>VESSEL TYPE</th>
<th>Recorded Number of Vessels Visits</th>
<th>Projected Number of Vessels Visits</th>
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<tbody>
<tr>
<td></td>
<td>91/92</td>
<td>92/93</td>
</tr>
<tr>
<td>BULK CARRIERS</td>
<td>23</td>
<td>12</td>
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<tr>
<td>FISHING</td>
<td>784</td>
<td>751</td>
</tr>
<tr>
<td>LIVESTOCK</td>
<td>71</td>
<td>105</td>
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<tr>
<td>RIG TENDER</td>
<td>225</td>
<td>170</td>
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<tr>
<td>OTHER</td>
<td>362</td>
<td>351</td>
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<tr>
<td>TOTAL VESSELS</td>
<td>1,465</td>
<td>1,389</td>
</tr>
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</table>

Source of data: Northern Territory Department of Transport and Works, October 1993

Environmental Impact Statement
Darwin Port Expansion - East Arm
Acer Vaughan Consulting Engineers
Consulting Environmental Engineers
LIST OF CORAL FAMILIES Recorderd

Acropora  
Cynarina  
Diploastrea  
Duncanopsammia  
Echinophyllia  
Euphyllia  
Favia  
Favites  
Galaxea  
Goniopora  
Heteropsammia  
Hydnophora  
Leptoseris  
Lithophyllon  
Lobophyllia  
Merulina  
Montastrea  
Montipora  
Oulophyllia  
Pachyseris  
Pectinia  
Platygyra  
Porites  
Symphyllia  
Turbinaria
<table>
<thead>
<tr>
<th>SITE</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCATION</td>
<td>Shell Islands</td>
<td>Wickham Point</td>
<td>Swires Bluff</td>
<td>Blackmore Pt Rocks</td>
<td>Oyster Rocks</td>
<td>South Blackmore Pt Point</td>
<td>South Blackmore Pt Rocks</td>
<td>Channel Island</td>
</tr>
<tr>
<td>BIOTA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turbinaria</td>
<td>16</td>
<td>9</td>
<td>14</td>
<td>6</td>
<td>5</td>
<td>10</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Goniopora</td>
<td>12</td>
<td>3</td>
<td>1</td>
<td>14</td>
<td>20</td>
<td>2</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Plate corals†</td>
<td>6</td>
<td>7</td>
<td>0</td>
<td>37</td>
<td>0</td>
<td>37</td>
<td>24</td>
<td>20</td>
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<tr>
<td>Hard corals‡</td>
<td>9</td>
<td>17</td>
<td>1</td>
<td>39</td>
<td>1</td>
<td>34</td>
<td>42</td>
<td>36</td>
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<tr>
<td>Sponge</td>
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<td>0</td>
<td>19</td>
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<td>1</td>
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<td>3</td>
<td>6</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Bare</td>
<td>24</td>
<td>32</td>
<td>75</td>
<td>7</td>
<td>52</td>
<td>15</td>
<td>18</td>
<td>22</td>
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<tr>
<td>Depth</td>
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<td>3.5</td>
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<td>7.0</td>
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<td>6.0</td>
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<tr>
<td></td>
<td>Mean</td>
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<td>4.7</td>
<td>3.9</td>
<td>4.8</td>
<td>5.0</td>
<td>5.0</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Note: † "Plate corals" include plate-forming coral, excluding Turbinaria
‡ "Hard corals" include non-plate forming corals, excluding Goniopora

Environmental Impact Statement
Darwin Port Expansion - East Arm
Acer Vaughan Consulting Engineers
Consulting Environmental Engineers
Table 5-2
FIGURES
BIRD SPECIES RECORDED IN PROPOSED SUPPLY BASE LAND AND MARINE-BASED AREAS IN JUNE 1990

<table>
<thead>
<tr>
<th>BIRD SPECIES</th>
<th>OVERHEAD</th>
<th>WOODLAND</th>
<th>MANGROVE</th>
<th>SAND/MUD FLAT AND REEF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Varied Triller</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lalage leucomela</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-winged Triller</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L. sueurii</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lemon-breasted Flycatcher</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microeca flavigaster</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mangrove Golden Whistler</td>
<td></td>
<td></td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Pachycephala melanura</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern Fantail</td>
<td>P</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Rhipidura rufiventris</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Golden-headed Cisticola</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cisticola exilis</td>
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<tr>
<td>Mangrove Warbler</td>
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<td>P</td>
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<tr>
<td>Myzomela obscura</td>
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**BIRD SPECIES RECORDED IN PROPOSED SUPPLY BASE LAND AND MARINE-BASED AREAS IN JUNE 1990**

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<th>OVERHEAD</th>
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<th>MANGROVE</th>
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<td>Double-barred Finch</td>
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<td>Figbird</td>
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<td>Magpie-lark</td>
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<td>Grallina cyanoleuca</td>
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<td>Black Butcherbird</td>
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<tr>
<td>Cracticus zuoyi</td>
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<tr>
<td>Great Bowerbird</td>
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<td>Chlamydera nuchalis</td>
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<tr>
<td>Torresian Crow</td>
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<td>Corvus orru</td>
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APPENDIX E

MAMMALS AND REPTILES OBSERVED AT PROPOSED SUPPLY BASE SITE IN JUNE 1990

MAMMALS

Northern Quoll
Northern Brown Bandicoot
Northern Brushtail Possum
Agile Wallaby
Antilopine Kangaroo
Grassland Melomys
Feral Cat
Feral Pig

Dasyurus hallucatus
Isoodon macrourus
Trichosurus arnhemensis
Macropus agilis
Macropus antilopinus
Melomys burtoni
Felis catus
Sus scrofa

REPTILES

Prickly Gecko
Skink
Skink
Skink
Wall Skink
Blue-tongue Skink
Northern Sand Goanna

Heteronotia binoei
Carlia gracilis
Carlia munda
Carlia rufilatus
Cryptoblepharus plagiocephalus
Tiliqua scincoides intermedia
Varanus panoptes
As requested, the following outlines the modelling work undertaken to assist the preparation of the above statement.

The Darwin Harbour numerical model was used to predict changes in the hydrodynamic behaviour in the East Arm due to the proposed port development. Also it was used to examine the dispersion of a suspended sediment plume generated by the discharge of return dredge water from the fill area to the harbour. The following information was supplied with respect to the hydrodynamic behaviour:

- modelling for existing, Stage 1 and Stage 3 development scenarios;
- neap and spring tidal velocity contours for 0.3, 0.6, 0.9, 1.2, 1.5, 1.8 and 2.1 m/s at times of 0, 2, 4, 6, 8 and 10 hours after high tide;
- neap and spring tidal velocity vectors at the times and tides listed above;
- time history plots of velocity at eleven points (mainly upstream of the development) for neap and spring tidal ranges for the existing and Stage 3 conditions; and
- distribution of suspended solids derived from dredging and discharge of return dredge water from the settling basins on the site during the construction phase.

The model results were provided for an extensive area of the East Arm extending from adjacent to the Darwin CBD to about 2.3 km upstream of the Shell Islands.

The tidal ranges adopted for the modelling were:

- neap : 1.8 m; RL 3.1 to 4.9 CD
- spring : 5.6 m; RL 1.2 to 6.8 m CD
Samples of the model results for the velocity vector plots, time history velocity plots and suspended solids distribution are attached. The original model results are contained in Section 19, Volume 2 of the Darwin Harbour Model report.

In the estimation of the dispersion of the suspended solids in the return dredge water during the construction phase, a number of characteristics were adopted in discussion with Consulting Environmental Engineers Pty Ltd which

- dredge return water discharge point from proposed landfill into the harbour to be located at mid point of Stage 1 reclamation;
- mean diameter (d50) of the suspended sediment in the return water - 0.02 mm;
- suspended sediment concentration in return water - 5,000 mg/L;
- discharge rate for return water - 1.5 m3/s;
- background and ocean water suspended sediment concentration - 20 mg/L;
- ocean water suspended sediment - d50 = 0.0075 mm;
- the moveable bed has a four layer system with the parameters:

<table>
<thead>
<tr>
<th>Layer</th>
<th>Critical shear stress newton/m2</th>
<th>Bulk density kg/m3</th>
<th>Thickness m</th>
<th>Dry density kg/m3</th>
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</thead>
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<tr>
<td>1</td>
<td>0.06</td>
<td>1,085</td>
<td>0.3</td>
<td>90</td>
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<td>2</td>
<td>0.12</td>
<td>1,120</td>
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<td>3</td>
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<td>1,220</td>
<td>0.1</td>
<td>310</td>
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<tr>
<td>4</td>
<td>0.40</td>
<td>1,350</td>
<td>0.05</td>
<td>550</td>
</tr>
</tbody>
</table>

- kinematic viscosity of suspending sediment - 1.16 x 10-6 m2/s;
- density of sediment - 2,700 kg/m3;
- critical shear stress for erosion - 0.06 newtons/m2;
- bed roughness - 0.01 m.

It was assumed that wave induced suspension of sediment would be neglected.

The RMA-2 model was run for 150 hours (over 6 days) with a constant spring tidal range input for both the Stage 1 and Stage 3 proposed developments to establish the velocity fields within the area of interest.
The RMA-4 model was used to simulate the dispersion and advection of the suspended solids from the construction activity to ascertain the extent to which the plume would inundate the pearl leases near the southern shoreline opposite Quarantine Island (east of Wickham Point).

This is a conservative examination of the issue as it does not allow for settling of suspended sediment and as such would tend to overstate the likely suspended sediment concentrations due to the construction activities. Also, it assumes a constant spring tidal range boundary input which would overstate the degree of dispersion and advection of the plume.

For the Stage 1 development, the plume would tend to remain on the northern side of the estuary flowing in either direction with the prevailing tidal currents. The suspended solids concentration contours have been plotted at times of 66, 72, 144 and 150 hours and are presented in Section 20, Volume 2 of the Darwin Harbour Model report. A sample colour plot of suspended solids concentrations for the Stage 3 scenario is attached.

This plume for the Stage 3 development scenario would tend to disperse to a larger degree within the estuary although the increases in suspended solids concentration at the pearl lease site are not significant compared to the values near the landfill site. After 150 hours of simulation, the concentration at the pearl leases had increased to over 30 mg/L from a background value of 20 mg/L. The concentrations at the leases are highest during an ebb tide.

Time history plots of suspended solid concentration at three locations, viz:

- Location A - near pearl leases;
- Location B - in Frances Bay;
- Location C - about 2 km upstream of Quarantine Island

are presented in Section 21, Volume 2 of the Darwin Harbour Model report. There are diurnal variations in concentrations both upstream and downstream of the landfill as would be expected due to the upstream orientation of the plume in a flood tide and downstream orientation during an ebb tide. Near the oyster leases there is minimal variation in suspended solids concentrations although at all three sites there is a gradual underlying increasing trend in suspended solid concentrations.

Yours faithfully

PATTERTSON BRITTON

M.S. Tooker
Director
Spring Tide, Velocities - High tide + 10 hrs
Attention: Stephen Pendle

Dear Stephen

SCOUR AROUND CATALINA ISLAND

Herewith time history plots of velocity at 3 selected locations around Catalina Island. As you can see there is an increase in velocity changing from existing to Stage 3 development. The tide selected was a springs tide.

This increase in velocity would suggest that scour will take place. However, Point A is subjected to a maximum velocity of about 0.6 m/s at present, and about the same for Stage 3. This suggests that scour might not take place at Point A.

For Points B and C, maximum velocities double from existing conditions to Stage 3 development.

Stage 1 velocities are not expected to change significantly from existing velocities.

It may be possible that the bed is armoured and that no scour will occur. If any further statements on the possibilities of bed movement are required, sediment samples will have to be obtained and the condition of the surface noted.

Yours sincerely

PATTERSON BRITTON

Barry le Plastrier
Associate
TIME HISTORY PLOT OF VELOCITIES AT POINT C CATALINA ISLAND, EXISTING CONDITIONS SPRINGS TIDE
APPENDIX G
ABORIGINAL ARCHAEOLOGICAL INVESTIGATION
EAST ARM PORT DEVELOPMENT
DARWIN HARBOUR

KEN MULVANEY
1993
ABORIGINAL ARCHEOLOGICAL INVESTIGATION
EAST ARM PORT DEVELOPMENT
DARWIN HARBOUR

Report prepared for
Acer Vaughan

By
Ken Mulvaney
May 1993

33 Rapid Creek Road, Millner, Northern Territory
089-855526
# TABLE OF CONTENTS

EXECUTIVE SUMMARY ................................................................. 1

1.0 INTRODUCTION ................................................................. 2

1.1 PREAMBLE ......................................................................... 2

1.2 ENVIRONMENT ................................................................. 4

1.3 VEGETATION ................................................................. 4

1.4 GEOLOGY ................................................................. 4

1.5 HISTORICAL INFLUENCES .................................................. 5

1.6 ABORIGINAL SITUATION .................................................. 5

2.0 ARCHAEOLOGICAL DATA ................................................... 6

2.1 PREVIOUS STUDIES ................................................... 6

3.0 METHODOLOGY ............................................................... 7

3.1 SCOPE OF SURVEY ............................................................... 7

3.2 VISIBILITY & DETECTION ................................................... 7

3.3 SURVEY & RECORDING STRATEGY ....................................... 8

4.0 RESULTS OF SURVEY .......................................................... 9

4.1 ARCHAEOLOGICAL SITES .................................................. 9

4.2 NON ABORIGINAL SHELL SCATTERS .................................. 11

5.0 SIGNIFICANCE ................................................................. 11

5.1 MEANING OF SIGNIFICANCE ............................................ 11

5.2 ABORIGINAL ARCHAEOLOGICAL SITES .................................. 12

6.0 ASSESSMENT OF IMPACT ................................................... 14

6.1 GENERAL CONDITIONS ................................................ 14

6.2 SPECIFIC ASPECTS .................................................... 14

7.0 RECOMMENDATIONS ...................................................... 15

8.0 REFERENCES ................................................................. 16
EXECUTIVE SUMMARY

As part of investigations in relation to the preparation of an Environmental Impact Statement, the consultant was contacted by the company Acer Vaughan to undertake an Aboriginal Archaeological survey of the area proposed for the future Darwin port facilities at East Arm. This report relates to the archaeological survey conducted in the location of this proposed development, and was carried out during mid May of 1993. To improve survey conditions and ground surface visibility, fires to clear vegetation were deliberately lit prior to commencement of this archaeological survey.

The area of the East Arm development includes the land of Quarantine Island, separated from the mainland by tidal mudflats and now linked by a bitumen road, and the three off shore islands, that of Catalina Island, and North and South Shell Island. Much of the mudflats and area of mangroves surrounding Quarantine Island is included within the study area, as well as a small section of the mainland adjacent to this island.

Extensive modification to the area concerned with this Aboriginal archaeological investigation occurred during the 1940's. This associated with several military bases, with accommodation barracks, office buildings, workshops and other facilities having been constructed in the area, much of this linked with a section of the Allied Intelligence Bureau. The Catalina (flying boat) operations were also established at this location, utilising both the mainland and islands (Dermody 1991). One of the site of Darwin's quarantine stations was based here at East Arm, and remained in service until the mid 1950s. As a result of all these activities in this area, there still exists many historic structures and earth works in evidence. In consequence much of the natural landscape has been modified or destroyed. More recently the Darwin Cement works have been established out in this location, and a slate company factory adjacent to the public boat ramp are positioned at the southern end of East Arm.

Despite destruction of the natural area resulting from these developments, three Aboriginal shell middens exist within the project area, as well one isolated artefact (a flaked stone point), lies within an area that at one stage has been cleared. A quartz core and several flakes are located near the top of a ridge toward the southern end of Quarantine Island in an area extensively disturbed during the war and associated with the quarantine station. One of the shell scatters identified during this survey is situated on the northern point of Catalina Island, a small rocky island off the coast of East Arm. There is an extensive midden located near the Territory Slate Factory, in the area of the jetty and slipway associated the RAAF Catalina Base. The third Aboriginal archaeological midden is adjacent to the mudflats located on the western side of the cement works.

There is the potential that an in-situ Aboriginal shell midden exists among the remains of Second World War structures at the northern end of Quarantine Island. Further investigations including test pit excavations may be required to establish the formation processes of this shell deposit. No other Aboriginal archaeological material was recorded within the project area. Though a number of shell scatters do occur within the area of the quarantine station, these are interpreted as resulting from European activities, being associated with the construction of the 1940s buildings.

As a result of this Aboriginal archaeological investigation it is recommended that some modification to the preliminary design of the port development is done. This is intended to protect and preserve the Aboriginal cultural sites in the East Arm area. If such an option is not feasible then detailed recording including excavation must be undertaken at those places likely to be destroyed. This should include the removal for analytical study of the quartz artefacts.
1.0 INTRODUCTION

1.1 PREAMBLE

As part of the preparation for an Environmental Impact Statement (EIS) a survey for Aboriginal archaeological sites was undertaken. The study area relates to the location of proposed development for a new Darwin commercial port facility, that is to be situated within the area of East Arm. It is proposed that facilities, including container terminals, storage areas and port buildings be situated within the channel off Quarantine Island. Mooring bays to be located in Darwin Harbour situated in the area of North Shell Island and extending eastward toward Catalina Island and south toward South Shell Island. Land fill for this proposed development will come from Quarantine Island, and presumably from material derived from the dredging of the required shipping channel.

Quarantine Island is located six and half kilometres to the east south east of the central business district of Darwin, and is some twenty kilometres away by road. It is a hilly promontory surrounded by mangroves and mudflats on all but the southern aspect. Here on the southern side and facing out to Catalina Island are sand and stony beaches with fringing mangroves.

The study area of East Arm in addition to including Quarantine Island and the associated mudflats (an area of less than two square kilometres), the three islands of Catalina Is., North Shell Is. and South Shell Is. are included. Archaeological investigations were conducted over most of this area, though no on ground survey was carried out on the mudflats or South Shell Island, these areas inundated by the sea during high tides.

The area of Quarantine Island and to a lesser extent that of Catalina Island have been the focus of European activities that have to an extent modified the natural landscape. This having the potential of masking or possibly destroying earlier Aboriginal archaeological material. European use of this area include the establishment of a quarantine station, and during the Second World War, military bases associated with the RAAF Catalinas and operations centre for commando activities into southern Asia.

Archaeological sites and cultural objects protection is covered by the Heritage Conservation Act 1991, which is administered by the Heritage Unit of the Conservation Commission of the Northern Territory (CCNT). This legislation is intended to cover not only archaeological sites, including both Aboriginal and Australian historic places, but is concerned with natural features and the built up environment (architectural value). This situation, both with the drafting of the legislation and in the administration of the Act, have not been totally satisfactory, nonetheless all Aboriginal cultural material and sites are safeguarded with this legislation.

Prior to the introduction of this heritage legislation, Aboriginal archaeological concerns came under the Native and Historical Objects and Areas Preservation Act, managed by the Northern Territory Museum. Until the introduction of the new legislation the staff at the Northern Territory Museum formulated job briefs for archaeological investigations and assessed the competences of the work and validity of the findings. This situation is no longer operable, and guidelines for the East Arm
investigation are supplied by the company Acer Vaughan Darwin Pty. Ltd. This consulting engineers company is contracted to produce the EIS for the East Arm Port development. The requirements to the archaeological consultant includes, for information to be supplied on the survey strategy adopted by the consultant, descriptions of all Aboriginal archaeological resources that may occur within the project area, and assessment of significance. These matters are addressed in the body of this report along with relevant data and other information which enables an appraisal of the nature of the local archaeology, and the potential impact of the port development proposals on these cultural resources.

Findings of this Aboriginal archaeological investigation are that there exists a number of shell concentrations throughout the area of Quarantine Island, though only two of which are regarded as being of Aboriginal formation. One of these shell middens is located on the beach dune defined at the southern end by the slate factory and to the east by Second World War facilities. The other site is adjacent to the mangroves located on the western side of the cement factory. A third shell midden is located on the northern point of Catalina Island, this like the one near the cement works is small. There are a number of other shell scatters present within the project area, these are situated in association with the remains of historic structures and are interpreted as relating to these features, rather than of Aboriginal agency. At three locations quartz artefacts occur, two locations within the area of the quarantine station, the other on the midden site on Catalina Island.
1.2 ENVIRONMENT

The natural environment, climate, vegetation and geomorphology, all influence how people exploit and occupy the landscape, as well, have relevance in the situation and condition of archaeological sites. The current situation of the islands and coastal mudflats with fringing mangroves could only have become established with the rise in sea levels following the last global glaciation. Studies in the Kakadu region put the stabilisation of the sea level at about 6,000 years ago, and until then this area would have been a series of higher points within an inland plain. During the glacial period (c. 25,000 to 15,000), sea levels dropped, and the area would have become much drier and cooler than conditions prevailing today.

The current climatic conditions for the area is that of a monsoonal pattern characterised by a wet summer and dry winter. Records of the weather patterns of Darwin are for an average annual rainfall in the order of 1660mm, almost all of this coming in the months November through to March. This part of the year is influenced by the north-west monsoon troughs, with torrential rains and extensive flooding brought on by thunder storms and tropical cyclones. During this part of the year average daily temperatures are 33°c and humidity over this period averages 70-80% though does rise higher.

The dry season is dominated by the south-east trade winds, and rarely is rain recorded through this part of the year. In the northern winter, monthly maximum temperatures are in the order of 30-32°c. July is the coldest part of the year with minimum average at 19°c, and occasionally temperatures may drop to 16°c. Humidity over this period is more tolerable with relative levels of below 40%.

1.3 VEGETATION

There are a number of distinct vegetation communities in the East Arm area, with open woodlands dominated by eucalypts and mangroves most widely occurring (Wilson et. al. 1990). In places other species occur including milkwoods (Alsonia actinophylla), cypress pine (Callitris intratropica) and coconut palms, most the result of planting associated with the European settlement of the location. Common tree species in the woodlands are Eucalyptus miniata (Darwin woolly butt) and E. blesseri (smooth-stemmed bloodwood), others found are E. tectifica (northern box) and E. tetradonta (stringy bark). Some variation of community dominance and frequency of accompanying vegetation is apparent between rocky areas, the slopes and fringing the mangroves. Pandanus spiralis and stands of Melaleuca sp. occur in areas that are more poorly drained and in a few locations abut the mangroves. The area of eucalyptus woodland is characterised by a Spear Grass grassland understorey, comprises tall annual grasses primarily Sorghum intrans and S. stipoideum, and with perennials S. plumosum, Heteropogon triticeus and Sehima nervosum.

1.4 GEOLOGY

The study area can be divided into distinct land systems, the coastal plains, tidal mudflats and offshore islands. Two of the islands, that of Catalina and South Shell Is. are formed by outcropping rock. Catalina also has fringing shell beaches and a shallow soil present along part of the crest to this island. Rock formations are also evident on North Shell Island though the majority
of this island is built up of shell grit. The tidal flats comprise estuarine muds derived from the
surrounding mainland and formed relatively recently with the flooding of Darwin Harbour during
the Quaternary period. The bordering slopes and rises comprising Quarantine Island and the
mainland proper are characterised by rocky outcrops and relatively shallow soils. Sandstones and
siltstones comprises much of this. There are numerous outcrops of quartz, varying in size and
quality, though none of these exposures appears to have been exploited by Aboriginal people.

1.5 HISTORICAL INFLUENCES

Use by Europeans of the East Arm area during the past sixty years has been extensive, and the
effect on the Aboriginal usage of this area and in the preservation of Aboriginal archaeological
material has been adverse. In the early 1930s a quarantine station was established at this location
and remained in operation until relatively recently. During the Second World War this location
was utilised by the military as their base for insurgency groups operating in the south Asia region.
In 1942 a joint Dutch and Australian group established their base on Quarantine Island, and
construction of a number of buildings including a hospital and latrines. Later the number of
structures was increased and included separate mess and ablution facilities for officers, soldiers and
"natives" (Dermoudy 1991). An RAAF base for the flying boats was also established in this area,
and by late 1943 maintenance workshops and other facilities has been constructed. The catalina
flying boats where moored off the islands, some of which having been sunk during Japanese
bombing raids on Darwin are still in the area, and these wrecks provide popular recreational diving
and fishing spots.

Most of these war time facilities are located along the southern and south-eastern sector of
Quarantine Island, with the quarantine station slightly north of these. Over a low hill on the
northern end of this island are the concrete floors of numerous buildings, these also date from the
Second World War.

In more recent times a number of boat ramps for recreational use, as well used by commercial pearl
farming operations, have been constructed at East Arm. Two commercial operations are also
located out in this area, that of the slate factory positioned at the southern end of Quarantine Island,
adjacent to the present boat ramp. The other is that of the Darwin Cement works and is located at
the north-western end of Quarantine Island. These and the various powerlines and numerous roads
and tracks throughout this area have resulted in extensive modification to the landscape over this
historical period.

1.6 ABORIGINAL SITUATION

This part of Darwin harbour is within the country traditionally associated with the Larakia
Aboriginal group. They are regarded as a saltwater people and relied heavily on marine resources.
The establishment of European settlement within their country has caused major disruption for
these people, and it is likely that with the development of the quarantine station and military
operations at the East Arm location, that Aboriginal usage of this area was curtailed. One old
Larakia woman recounts however, that people did fish in this location using canoes to go out to the
islands (Mearns pers. com.).
2.0 ARCHAEOLOGICAL DATA

2.1 PREVIOUS STUDIES

There has been little research work carried out in the Darwin area, and even fewer studies in relation to development projects. An inspection of the Northern Territory Museum register indicates that within the area of the East Arm project two shell midden sites are known. Both sites were identified during recreational activities, and as a consequence only superficial recording of these places exists. Other shell midden sites are reported for locations in the Darwin Harbour area, some in addition to containing food refuse, stone tools (axes) and other lithic material have been reported. Off the coast at Nightcliff is the remains of a stone walled fish trap, such features utilised the tidal movement to entrap fish behind the walls and are common throughout much of Australia.

One of the few investigations into the potential existence of Aboriginal archaeological sites within proposed development areas occurred in relation to the Bayview Haven Project. This proposed development is for an urban residential canal estate focused on Sadgroves Creek, located within Darwin Harbour some five kilometres north west of East Arm study area. Only the higher, fringing areas to the Mangroves was considered for archaeological investigation, and due to dense vegetation cover of the area, a sampling strategy that further reduced the area inspected was adopted (Palmer 1991). In this investigation one shell midden was recorded, exposed along an existing track and with evidenced of a deposit up to fifty centimetres thick. *Anadara granosa* dominated the shellfish species present at this site, other molluscs species identified are *Telescopium telescopium* and *Terebralia sulcata*. A number of small shell scatters were found throughout the study area, these interpreted as of recent formation (Palmer 1991).

Two follow up investigations have been conducted in relation to shell material located in the original Bayview Estate survey, each were a specific assessment of the sites (Guse & Hiscock 1993 and Hiscock 1992). The higher ground within the development area was also included in this subsequent work.

It was recommended that should the proposed development proceed then a salvage excavation and additional recording of this shell midden located within the Bayview Haven Estate occur. Recently people from the Department of Anthropology at the Northern Territory University undertook this work. Analysis of the data has been completed and a draft report produced (Guse & Mowat 1993). Four stratigraphic units are identified, though there is only scattered fragmentary shell in the third layer and no shell within the basal deposit. Analysis of the shell species uncovered during this excavation confirms Palmer’s assessment of a *Anadara granosa* dominated midden, however many more bivalves and gastropods are identified, with most species available from the mudflats and mangrove stands (Guse & Mowat 1993: 8).

Early in 1992 an archaeological investigation was undertaken of the area in Middle Arm of the proposed Haycock Reach Aquaculture Development (Kinhill 1992). The results of this survey were that seventeen archaeological sites were located, of these eight are stratified shell middens, six are surface scatters of shell associated with Aboriginal exploitation and one surface scatter of stone artefacts. Three others sites were identified that are shell concentrations either modified by Second
World War emplacements, or material brought in from elsewhere for construction purposes. Anadara shell dominated the mollusc species present at all these sites, and within the stratified shell middens numerous quartz artefacts were observed. The focus of this survey was of the areas adjacent to the present coastline and did not extend far inland. Vegetation density also created survey difficulties, and subsequent investigations at Haycock Reach and further afield, along Middle Arm, have shown that anadara middens, including large mounds occur widely. Research work by Hiscock and Hughes supported by carbon fourteen dates indicate, for the Haycock Reach area at least, that shell midden material accumulated during the late Holocene, and that such accumulation had apparently ceased by 500 years ago (Hughes pers. com.).

3.0 METHODOLOGY

3.1 SCOPE OF SURVEY
The guidelines provided in a letter from Acer Vaughan (dated 28 April 1993) outlining their requirements for an Aboriginal archaeological survey pertaining to the preparation of the East Arm Port development Environmental Impact Statement and stipulates:

- conduct a field survey to identify and describe any significant archaeological sites within the study area.
- provide details pertaining to the scope of the survey and the methodology adopted.
- provide site descriptions, diagrams and maps.
- outline any further action required in relation to identified sites.

Under the current legislation a permit is required, authorised by the relevant Minister, in relation to works which may result in disturbance to any archaeological site or object, or for the collection of material including that for scientific excavation (section 29 & 39 Heritage Conservation Act 1991). In essence it is necessary prior to any proposed development works, to locate archaeological features within the relevant area, and provide information concerning these, that will allow for the Minister to formulate a responsible decision in relation to any Aboriginal sites or objects that may be adversely affected by the proposed developments.

Archaeological assessments are also a federal requirement under the legislation pertaining to the processes of an Environmental Impact assessment.

3.2 VISIBILITY & DETECTION
One of the primary factors influencing the effectiveness of archaeological field surveys is the ground surface visibility and accessibility within the project (study) area. Here in the top end of the Northern Territory the pattern of dramatic climatic conditions with torrential rains and localised flooding during the wet season, and the associated vigorous growth of annual grass, makes for problematic and trying survey conditions. The growth of Spear Grass that at times attains heights of several meters and can form almost impenetrable areas, in effect reduces ground surface visibility to a minimum. As a consequence of these conditions the archaeological consultant
requested of Acer Vaughan to arrange for a controlled burn of vegetation within the proposed project area.

This clearing of the grasses through burning occurred in the week of the 12 May, and the archaeological survey took place following this. The burn off was not as extensive as had been requested, the bitumen road unfortunately acted as an efficient fire break. Only that area on the eastern side of this main access road was cleared of the Spear Grass, and even in this sector this was patchy.

3.3 SURVEY & RECORDING STRATEGY

The study area can be divided into three distinct zones or land systems that are pertinent to the nature of archaeological sites and the likely identification of material, these being:

- The three off shore islands of Catalina, North Shell and South Shell Is.
- The eucalyptus woodland of Quarantine Island and the adjoining mainland of East Arm.
- The tidal mudflats and fringing mangroves surrounding Quarantine Island and adjacent to the main land.

Prior to commencing the field survey, aerial photographs (normal and infra-red) of the study area were inspected. These photographs taken during high and low tides and over a span of decades were utilised to identify if archaeological features such as fish traps or raised mounds existed, especially within the tidal mudflats area. Such features are generally of high visibility, and as none were detected and that the mudflats are inundated during high tides this land system within the project area was not inspected on foot. A complete traverse was made however along the edge of the fringing mangrove both associated with Quarantine Island and the adjacent mainland within the project area.

Two of three off shore islands were inspected on foot, covering the entire area of each small island. The third island, that of South Shell Is. was not investigated as this island is inundated during high tides and it is unlikely that Aboriginal people would have utilised this island as they would the others, and in any event the probability of archaeological material remaining in-situ under such conditions is remote in the extreme.

Surveying of Quarantine Island involved the maximum coverage of the area. In the sector east of the bitumen road, where the burn off had been most effective, the area was traversed in sections, using natural as well historic features to define the internal survey boundaries, and thus ensuring all areas were inspected. The intention was to obtain a total coverage of the area. On the western side of the bitumen road a narrow section where vegetation cover still posed difficulties two traverses were made, one along the mangrove fringe where weathering has exposed much of the coastal edge of the landmass. The other transect positioned slightly inland of this, and effort was made to inspect all exposed ground surface areas. In this particular section of East Arm it has been used as a dumping ground both for commercial and domestic rubbish, as well some areas have undergone alteration through relatively recent earthworks including an earlier boat ramp.
In the area toward the northern end of Quarantine Island, bounded by the mudflats the cement works and the bitumen road, this area was traversed by foot. Density of vegetation and the existence of the floors of numerous historic buildings ensured that coverage was by a random and irregular traverse spacing and direction. Though here again the area adjacent to the mangrove fringe was inspected in entirety.

All Aboriginal archaeological sites and other features that contained shell concentrations not of natural origin where marked by attaching pink flagging tape to nearby vegetation. This is done to aid relocation if further documentation of these places is required, and to make identification of Aboriginal archaeological sites on the ground easier for persons involved with the development project that may not be familiar with archaeological material. All places of interest were identified and marked on an aerial photograph, this ensures accurate location of these sites, and will assist in the formulation of strategies for the protection or recovery of these sites.

4.0 RESULTS OF SURVEY

4.1 ARCHAEOLOGICAL SITES

Three Aboriginal archaeological sites were identified within the project area, two of these are on Quarantine Island the other is located on Catalina Island. The largest of these is located at the southern end of Quarantine Island immediately behind a narrow beach, fringed on the seaward side by mangroves (plate 1). Within a slightly raised dune parallel to the beach, shells are exposed in the actively eroding face, this extends for over 90 meters in a band three meters wide. The southwestern end is determined by the disturbance associated with the slate factory and relatively recent earthworks, the north-eastern end is cut by some of the Second World War facilities. Though it does appear that this site is associated with a narrow spit of land with the sea on one side and a relatively level marshy area to the north. Modern rubbish is scattered over much of the site, and in several places the low sand ridge has been cut through by vehicles gaining access to the beach (plate 2, 3 & 4). A rich organic soil is associated with this site, and where exposed, indications are of a stratified midden deposit to a depth of at least twenty centimetres (plate 5, 6 & 7). *Anadara granosa* dominates the shellfish species present at this site, and other mollusc bivalve species identified are *Marcia hiantina*, *Crassostrea sp.* (oyster) and *Geloina coxanis*. This latter shellfish remains appear to be recent. Gastropods present are *Telescopium telecopium*, *Terebra palustris*, *Nertia balteata*, *Volegalea wardiana* and *Chicoreus capucinus*. No stone artefacts were observed within this deposit though this is not to say such material could not exist at this site.

The shell deposit on the northern end of Catalina Island is less defined with only a narrow band of archaeological material within a sandy and shell grit deposit. The site is on a narrow beach overlying rock and is partially covered by vegetation (plate 8). Midden material is concentrated in an area five meters wide and is visible between vegetation cover for some seven meters, this is relatively low in density and much beach washed material occurs amongst the archaeological deposit (plate 9 & 10). *Anadara granosa* predominated the shellfish species present at this site, other molluscs species identified being one fragment of *Telescopium telecopium* and possibly the small amount of oyster, chiton and nerita relate to Aboriginal origins, and are not part of the beach
deposit. Present at this site are two lumps of quartz, both appear to have a single flake scar, it is likely that these two artefacts were brought to the island, there being no quartz outcrop observed at this location.

Situated on the western side of the cement works, adjacent to the mangroves is a sparse scatter of shell that clearly relates to human agency. This site is situated just above the high tide level on the edge of the mangroves. As with the other sites Anadara granosa is dominant with other molluscs species identified being Telescopium telescopium and Terebralia palustris, Nerita balteata and Cerithidea obtusa. Along the high tide mark in this area as with other sections of the coastal margin are isolated shells almost all are either Cassidula angulifera or Cerithidea obtusa. The composition of the small scatter of shells near the cement works does not pattern this and thus supports the interpretation that this site is a small midden of Aboriginal origin.

An isolated artefact was located during this survey situated in an area that appears to have been cleared of native vegetation and surface rocks, this disturbance likely associated with the quarantine station. The artefact is a bifacial point, produced on a quartz blade (plate 11). This artefact measures 47 millimetres in length though the tip is missing, is 28 millimetres at its widest and 8 millimetres maximum thickness. The only other stone artefacts identified that occur within the study area are near the top of the ridge located several hundred meters south of the bifacial point and are situated in an area extensively disturbed by construction of buildings and subsequent demolition of these structures. One core measuring 111 by 58 by 57 millimetres with one larger and several smaller flake scars, and near by three flakes comprise the artefacts of this site. None of the flakes conjoin with the core, though all artefacts occur in an area of 150 by 40 centimetres. These quartz artefacts lie among numerous and relatively modern items and rubbish.

A shell scatter is located on the top of the hill at the northern end of Quarantine island and situated in an area of dense vegetation positioned amongst concrete floor slabs (plate 12 & 13). An extremely dense concentration of anadara shell and shell fragments occur over an area of 19 meters by 7 meters, with material present over a wider area of some 25 meters by 20 meters (plate 14 & 15). This material with the predominance of a single species is characteristic of Aboriginal middens in the Darwin Harbour area, however it is unclear as to how the shell material came to this particular position. In addition to those locations in the Haycock Reach area several other Second World War gun emplacements constructed from Aboriginal shell material have been found (Hughes pers. com.). In the immediate area of this shell scatter on the hill at the northern end of Quarantine Island are shell pieces contained within the concrete, evident in section and within the surface of the floors. With one of these floor slabs that has broken away, shell is visible in the fill used to raise the ground level on which the concrete slab was laid (plate 16 & 17). In addition, through the main shell deposit are European objects including glass fragments and bottle caps. A number of other European objects are present in the area, the largest item is an old cast iron stove. There exist indications at this location that the shell has been incorporated into the construction of Second World War structures, however currently there is not sufficient information to determine if the shell material is in-situ or has been brought in from an Aboriginal midden located elsewhere.
4.2 NON ABORIGINAL SHELL SCATTERS

There exist a number of concentrations of shell (edible species) that occur throughout the study area, however based on various factors these scatters are not interpreted as resulting from past Aboriginal usage. They are included nonetheless in discussion of this East Arm survey.

In the area of the quarantine station there are a number of concentrations of shell (anadara dominated), of these the largest scatter is situated along the ridge at the southern extent of the area associated with the quarantine station. The pattern of this shell scatter is that of fragments of the larger mollusc and intact or fragmented shell of the smaller species like limpet and oyster. This material is spread over an area of 50 meters by 15 meters, varying in density from very low to low (plate 18 & 19). The character of this material is reminiscent of storm beach deposit consistent with the fragmentary nature of shell and presents of non edible marine species like coral. Shell material does not extend down the slope toward the shore, which should be expected if the deposit did relate to storm surge action. It is more likely that the shell deposit was introduced to the location in association with the quarantine station, this is supported by the presence in this area of the remains of house platforms and much building debris.

To the north, off the ridge, in an area where a number of concrete floor slabs remain are several discrete scatters of shell and shell fragments (plate 20). These vary in extent, much of the material is confined to areas of approximately five meters by two meters though shell can be found over a wider area, up to 17 meters in extent. The shell at these locations appears to be associated with quartz gravel and small stones, as well a compacted red earth (plate 21). It is interpreted that these shell features are not Aboriginal archaeological deposits but are in some way associated with the quarantine station, and may be the floors of temporary structures. Mollusc species represented at these smaller sites, like that of the more extensive scatter along the ridge, are Anadara granosa, Gafrarium tumidium, Nerita balteata and Telescopium telescopium.

Occasional concentrations of shells were observed within the East Arm study area, these comprised of a few shells, usually of a single species, either Anadara granosa or Telescopium telescopium. Such features are interpreted as of recent origin and in some cases the remains of a near by fire is evident. These places are generally located down near the waterline and most likely relate to people collecting and eating the shellfish in proximity to where the food stuff was obtained or brought ashore. There where however two locations at which no fire was evident and that these concentrations where slightly more disperse and situated away from the mudflats or coastal fringe. Both occurred under larger trees and it is felt that birds may have transported the material to the trees and having fed subsequently dropped the remains to lie in their present position.

5.0 SIGNIFICANCE

5.1 MEANING OF SIGNIFICANCE

The value placed on heritage resources is based on a range of criteria and subjective opinion, but in general it can be said that the importance of a particular cultural heritage resource is judged on the extent and nature of information retrievable (scientific significance), as well that of aesthetic and
social importance (cultural significance). A number of factors need to be considered in formulating judgement of significance. For the archaeologist these include the amount of information a site may offer regarding past human activities and behavioural patterns that could provide an insight into prehistoric societies. Sites that contain a range of material and evidence of internal structure (features), can reveal a lot about the people whose activities created the site. That is, the quality and quantity of information that is potentially retrievable indicates the particular site's research value. Other criteria used in the assessment of significance are those of rarity, or the antithesis of this, the representativeness. That is, a particular site or object will be ascribed value if occurrence is known to be limited, or conversely, if such a feature is common and the particular site is a typical example of this, then the site's representativeness value is increased. The age or antiquity is also a factor in significance determination, though in general things of great age are also often unique, and thus have rarity value also. Linked to these, other principles that are important considerations are the state of the site or object and the integrity of the place, this includes the preservation condition, as well as the degree of displacement to features or contents within a site.

Cultural significance is equally important, and in some situations, especially so in the matter of Aboriginal archaeological resources, these considerations over-ride those of scientific significance. Value maybe ascribed through religious association, ethnic affiliation, or genealogical relationship, and such issues are prominent in the cases of human skeletal remains and sacred places. Other criteria which are considered non-scientific, being those of artistic or aesthetic standard and potential interpretive value (educational). These are not so much for the individual archaeologist to quantify, but rather they tend to emerge during public debate.

None of the significance assessment criteria, either scientific or cultural, are absolute and immutable, and significance may change or be reassessed as additional information is added or further research is undertaken.

It has been argued that for the archaeologist it is the scientific significance assessment, based on timely and specific research questions weighted against representativeness, that is of greatest importance (Bowdler 1984: 1). This research potential of the resource is primarily based on the current state of understanding and on the available technology at the time of the inquiry. For contemporary Aboriginal people that belong to an area, their concerns regarding sites is of relevance, and important in assessing management issues. Such cultural based significance is generally expressed in regard to their sacred sites, the burials, and historic camping places. These are generally accorded greater significance by the relevant Aboriginal group than is expressed over the prehistoric sites, though this is clearly not always the case.

5.2 ABORIGINAL ARCHAEOLOGICAL SITES

Of the three confirmed Aboriginal shell middens located within the study area the large site at the southern end of Quarantine Island is potentially of greatest significance. This site though parts have been destroyed or disturbed as a result of war time and post war developments, and by recent camping on the site and use of the area for the dumping of rubbish, nonetheless a large amount of the archaeological deposit remains intact. It is evident that at least 20 centimetres of shell material in a rich organic layer exists intact over much of this site. The potential research value of this
archaeological deposit is therefore high. This midden site is also the only large such concentration of shellfish remains within the project area, though other similar sites have been documented from other areas along the Darwin harbour coast line. From the few archaeological studies that have been conducted in this general area it is probable that this site too relates to a period of usage in the order of 1000 years ago, and that stone artefacts will be found within the deposit. It remains that this site is of archaeological significance and by conducting research can contribute to the understanding of the prehistoric occupation of the area.

With the other two shell middens they are relatively small, and in the case of the one at the northern tip of Catalina Island is partially exposed to disturbance arising through stormy seas. This site with the two flaked pieces of quartz is evidence that Aboriginal people did reach these harbour islands, and camped on at least Catalina Island. Due to the vegetation cover over this area it is difficult to assess the extent and integrity of this site, though it is likely to remain intact beneath the vegetation and that additional stone artefacts may also be present at this site. The other site located near the cement works does not appear to have any stratigraphy and comprises a narrow and sparse band of material exposed on the surface. This site is regarded as of low archaeological value though a detailed study of this shell scatter will contribute to the understanding of the pattern of Aboriginal usage of the area.

The occurrence of the quartz bifacial point as it appears to lie within an area where land clearance has taken place in relation to the quarantine station it is of uncertain antiquity. It is unlikely that it is in-situ (where it was discarded or dropped), nor is there any indication as to if this artefact predates the establishment of the quarantine station or was introduced into the area in more recent times. Due to these circumstances it is unlikely that there is any significant value in the artefact's present position in a specific sense. The artefact itself is nonetheless a good example of this type of implement, and the symmetrical shape of the point, formed as it is of quartz does indicate that the person that made this artefact had skill in working stone. There may be a research value in conducting further study of this artefact, especially given the development of analytical techniques in use wear and residue identification. It is likely that this bifacial point is of greater scientific value being removed and studied than remaining in it's present location.

Located as they are on the ridge at the southern extent of the quarantine station the quartz core and several spatially associated flakes are likely not in-situ. Much disturbance to the area has resulted in the construction, use and then demolition of buildings associated with the quarantine operations, and these artefacts occur within this general debris. The poorer conchoidal properties of this quartz means that the flaking features on these artefacts are less distinct than would be found on worked stone of better quality lithic. That these quartz artefacts result from actions resulting from the stone being struck unintentionally, possibly during demolition, and are not of Aboriginal agency remains a possibility. Further analysis may resolve the prospect of these items being of natural origin.

It is documented elsewhere that Aboriginal shell midden material is introduced to areas, and that middens where built on during the military occupation during the Second World War (Kinhill 1992). In two cases large shell midden mounds have both had pits dug into the sides and it is
inferred that this material was used in the construction of foundations for the concrete floor slabs of military structures in the Haycock Reach location of Middle Arm (Hughes per. com.). The circumstance of the large shell deposit on the crown of the hill at the northern end of Quarantine Island without further assessment presents uncertainties as to the origins of the material. There is no doubt that the shell derives from an Aboriginal shell midden. At this stage however, without test excavations to investigate the nature of this deposit it is not possible to determine if this material is in-situ, or has been introduced to the present location for use as construction material by the military during the Second World War.

6.0 ASSESSMENT OF IMPACT

6.1 GENERAL CONDITIONS

Much of the proposed development of facilities for the port are out in Darwin Harbour located off Quarantine Island. As is currently designed no activities or disturbance to Catalina Island is intended, located as it is on the eastern side of the proposed port facilities. In the current design plans only North Shell Island will be destroyed, though this eventuality does not relate to any archaeological sites. It is unclear as to the nature of impact of the proposed development of the port will have on Quarantine Island. At this stage it is envisaged that this island will supply land fill for the port construction, and possibly in the future commercial enterprises may be located in this area once the port is operational.

Under existing legislation all Aboriginal archaeological sites are deemed as prescribed places over which an interim conservation order is in force, Part 6 Heritage Conservation Act 1991. It is an offence to carry out works of any sort on, or damage, desecrate or alter, such a prescribed place (Section 34). In regard to those archaeological sites and objects located during this survey, and that lie within the area proposed for development, the Minister or the Minister’s delegate may by instrument in writing permit works to be carried out, or for the removal of objects (Section 29).

The developer should liaise with the Heritage Unit of the Conservation Commission of the Northern Territory in relation to these matters, and in determining procedures for further archaeological investigations or protection of the sites and isolated artefact.

6.2 SPECIFIC ASPECTS

6.2.1 As detailed in the current, though marked as preliminary, plan the area associated with the extensive midden situated above the beach at the southern end of Quarantine Island is identified for future port related usage.

6.2.2 Current design plans will not impact directly on Catalina Island, however the prospect remains that the island will still be visited by recreational fishermen and that construction workers or vessels will stop at this place.

6.2.3 No specific identification of the impact of the proposed port development is indicated for the area that the quartz bifacial point or the other quartz artefacts are located. It can be assumed
that this part of Quarantine Island is indented to supply land fill, if this is so then the artefact will likely be destroyed.

6.2.4 Impact on the shell midden located to the north-western end of Quarantine Island adjacent to the cement works is likewise unclear, though the proposed rail reserve passes over the location of this site. Indications are that the construction of a rail network is dependant on the Darwin to Alice line being constructed, so remains a distant possibility.

6.2.5 At this stage it is uncertain if the requirement for fill material will result in the removal of rock from the northern end of Quarantine Island. If this is necessary then the shell deposit in this location will be destroyed.

7.0 RECOMMENDATIONS

7.0.1 That design changes be implemented to ensure that the shell midden at the southern end of Quarantine Island remains undisturbed and measures be put in place to protected this site both during construction of the port and subsequent to this.

7.0.2 A less favourable option, and only if recommendation 7.0.1 is unfeasible, then a detailed recording and excavation of the midden occur, to document more fully this site and enable a greater understanding of the scientific and cultural value of this site. This must take place well in advance of any works commencing in this location.

7.0.3 Construction workers and equipment not utilise Catalina Island during the development of the port facilities, and that the midden site be monitored during the construction period to ensure that wave action resulting from works do not increase erosion of this site. If this is found to occur then action must be taken to mitigate this effect.

7.0.4 That collection and analysis of the quartz bifacial point, and that of the core and flakes situated within the area of the quarantine station occurs before further works take place in relation to the proposed port development.

7.0.5 If proposed development of the area on the west of the cement works proceeds, then prior to this a detailed investigation and analysis of the small shell midden in this location should take place.

7.0.6 The location of the historic structures and that of the extensive and dense shell scatter located on the hill at the northern end of Quarantine Island be preserved. The possibility remains that the shell at this location may derive from Aboriginal occupancy of this position.

7.0.7 A less favourable option, and only if recommendation 7.0.6 is unfeasible, then a detailed recording and excavation of the shell material at the northern end of Quarantine Island should occur. Part of this work will involve the assessment of this material as being an in-situ Aboriginal archaeological deposit.
8.0 REFERENCES


Guse, D. & P. Hiscock. 1993 Archaeological survey of the proposed Bayview Haven Estate shell midden. N.T. University, Darwin.


Kinhill Engineers. 1992 Aboriginal and historical archaeological sites. Appendix C, Haycock Reach aquaculture development Australian Frontier Holidays, Darwin.


ACKNOWLEDGMENT

Thanks to Ms. Fiona Mowat of the Northern Territory University who assisted in this Aboriginal archaeological survey, and put her expertise into good use with the identification of mollusc species and in discussions pertaining to the possible site formation factors responsible for the shell deposits located during this investigation.
Plate 1: View looking south westerly along beach at site of shell midden on the southern end of Quarantine Island. Midden material is along the beach edge and exposed tree roots and face to the midden indicate it may be actively eroding.
Plate 2: View taken from the northern side of the shell midden on the southern end of Quarantine Island. The building at right of photograph is the slate factory, and one of the tracks cutting this midden is to the left of view.
Plate 3: Remains of old jetty lying on the beach down from the shell midden, break in the midden was formed by this jetty and is now utilised for vehicle access onto the beach.

Plate 4: Detail of remnants of midden within the area disturbed by the old jetty and more recent damage by vehicle traffic onto the beach.
Plate 5: Detail of shell exposed in section along the low dune, note the rich organic soil and fragment of in addition to the anadara.

Plate 6: Anadara and terebralia fragment exposed in section scale in centimetres.
Plate 7: View of midden remains toward south-western end of site, note the plant growing over the midden, this is an introduced species and is confined to the rich soil associated with this midden.

Plate 8: View looking south toward the shell midden at the northern end of Catalina Island.
Plate 9: View of the midden area on Catalina Island, the two quartz artefacts are in the centre foreground.

Plate 10: Detail of the midden on Catalina Island, note the amount of naturally occurring shell grit and the apparent lens of shell relating to the midden.
Plate 11: Photograph of the quartz bifacial point.

Plate 12: View of the area of the shell scatter at the northern end of Quarantine Island, with part of one concrete floor slab in the centre foreground.
Plate 13: View looking toward the shell concentration at the northern end of Quarantine Island. Note the density of vegetation cover, the concrete slab at left of photograph, shell material is located behind bushes.
Plate 14: View of the shell scatter toward the northern end of Quarantine Island, note the old cast iron stove.

Plate 15: Detail of the shell whole and fragmentary, not only anadara but also terebralia.
Plate 16: Damaged concrete slab revealing shell and quartz gravel used in packing beneath the floor, these remains are on the hill at the northern end of Quarantine Island.

Plate 17: Detail of the section of one of the building slabs showing shells used in the concrete matrix.
Plate 18: Area of shell scatter on ridge within the area of the old quarantine station, with Darwin city visible in the distance and the cement works to right of view.

Plate 19: Detail of part of the shell scatter along the ridge, note the low density and variable state of the shell.
Plate 20: View of one of the discrete shell scatters within the area of the quarantine station.

Plate 21: Detail of the shell scatter, note the quartz and other stones and the compacted red earth.
HERITAGE ASSESSMENT

EAST ARM PORT DEVELOPMENT EIS

FOR

ACER VAUGHAN
CONSULTING ENGINEERS

PETER DERMOUDY
HERITAGE ARCHITECT

JULY 1993
HISTORIC SYNOPSIS

Quarantine Island was first occupied, by Europeans, as a quarantine station in 1931.

Following the outbreak of World War II, the island, along with its few hospital buildings and because of its remoteness and access for small boats, was allocated for use by the Allied Intelligence Bureau (AIB). The establishment began in December 1942\(^1\) and was given the cover name of Lugger Maintenance Section (LMS) to explain the presence and frequent coming and going of an odd collection of small vessels used in coast watch and other off-shore subversive and/or incursive operations. Slipways and workshops were constructed to service these vessels.

On the island, refugees and foreign nationals were de-briefed and prepared and trained along with Australians for insertion into Japanese occupied territories to conduct intelligence operations. It is perhaps best known for its part in the operations of "Z" Force where it provided administrative, supply and radio relay facilities. Such operations required the co-ordination of the three services of many allied nations.

Construction of a flying boat base was commenced in late 1942, about the same time as the LMS, but was not ready for full occupation until 23 September 1943. Prior to RAAF occupation the partially completed facilities were used by the US Navy to service its Catalina PBY flying boats—some of which, along with successive RAAF Catalinas, were used for clandestine insertion/rescue operations. A vital component of the facilities was the provision for work boats for fueling and arming moored aircraft. Thus, for security reasons, many of the nearby LMS boat handling facilities—slipways, jetties, workshops, fuel storage and battery charging—were duplicated.

RAAF No. 42 Squadron occupied the base briefly in June 1944 before moving its Catalinas to its new base on Melville Island in July. On 31 August 20 Squadron moved in from Cairns and became part of No. 76 Wing (with Nos. 42 and 43 Squadrons) with HQ at Doctors Gully.

On 10 December 1944, No. 112 Air Sea Rescue Flight (112 ASR) was formed by 20 Sqn. and was the last to leave the island following its disbandment in October 1947. 20 Sqn. was primarily engaged in mine laying operations in enemy ports and, following cessation of hostilities, was active in early evacuation of prisoners of war from nearby islands.

In 1948 most of the 'new' military facilities were sold by auction and the island prepared for re-occupation as a quarantine station. The LMS slipway and workshop (see PLATE 1) were retained for servicing boats used in connection with
Channel Island Leprosarium until its removal to the mainland in 1956.

In the early 1960's the timber wharf, built by the RAAF for its work boats, was destroyed by fire.

Between the mid to late 70's the island was pressed into its greatest post-war re-use by the influx of boats bearing refugees from warring Asian countries, principally Vietnam and East Timor. These people, who became known as the "Boat People", were to cause one of the greatest population upheavals Australia has experienced to date. The island was also used for the quarantine and detention of increasing numbers of crew of seized foreign fishing vessels - mainly of Indonesian and Taiwanese origin; until they could be tried and deported.

The Commonwealth retained ownership of the quarantine station until it was handed over to the NT Government on 14 May 1981. Two houses built post-war for medical staff were removed in 1990.

The export of uranium oxide (yellowcake) became subject to militant union reaction. In 1981, one of the Government's responses was to allow the use of the RAAF ramp for barge operations and the erection of a manproof fenced security holding yard on the remaining floor slab of the RAAF hangar, SITE 24. Modifications were carried out to the ramp which included the pouring of mass concrete to raise the level of the working surface to the level of the tops of the original raised edge-kerbs. During loading operations the island was closed to public access. This site was later leased for a time by Paspaley Pearling Co. Pty. Ltd. who used it and the ramp as part of its cultured pearl farming operations in East Arm.

Northern Cement Ltd. established a cement factory on the island in 1984 on land which included relics of WW11 camp sites and the original gravelled access road to the ramp which followed the western coastline. The current sealed access road, which effectively bisects the island, passed through further camp sites.

Rooney Shipping and Trading Pty. Ltd. leased land to the north east of the ramp for continuing barge operations between 1985-1986 and carried out extensive land levelling operations for turning and storage areas. This area is fenced and was used for a time by Transcom for abrasive blasting of structural steel components. It currently has a warehouse erected upon it and is jointly owned by Paspaley Pearling Co. Pty. Ltd. and N.T. Slate and Stone.
CURRENT AND FUTURE HERITAGE STATUS

At the time of writing, the only formal heritage listing of European sites on Quarantine Island is that of the National Trust of Australia (NT) which is non-regulatory and hence unprotectable by law. Some relic sites are also identified in the CCNT Coastal Resources Atlas which is advisory in nature and similarly without legal status at present.

It is possible the heritage sites outlined in this report as significant and recommended for preservation could be nominated to the Heritage Advisory Council for listing in the Northern Territory Register of Heritage Places and Objects, under the Northern Territory of Australia Heritage Conservation Act 1991. Should the Council decide that any such proposals have merit it would forward its recommendations to the Minister for his or her final decision upon their inclusion. The total process could take from one to six months.

It should be noted the Minister has powers on immediate notice, to issue an Interim Conservation Order should he or she be informed of a potential threat to a heritage place or object not currently listed but which might reasonably be considered for future inclusion.
HERITAGE ASSESSMENT OF SITES

Thirty three sites are herein listed as having remains identifiable as World War Two military sites and one (SITE 21) associated with the quarantine phase of the island’s history (refer to FIG.1).

Unfortunately, all other places and relics on the higher and flatter upper portion of the island which may have been associated with the island’s earlier history as a quarantine station (1931-1981) were demolished and levelled in 1990.

The thirty three sites mentioned above are concentrated largely on the coastal fringes of the island. Being of military origin the majority of the buildings on these sites were sold through the Australian Disposals Commission in 1946 although some, mainly the slipway (SITE 18) and workshop (SITE 17) were retained for use by small craft servicing Channel Island Leprosarium until it’s transfer to the mainland in 1956.2

The choice of heritage sites in this report was not made solely because they contained built relics but because of the relics’ value in establishing the location of and interpretation of the place.

It cannot be disputed the true heritage of the island lies in its pre and post-war uses as a quarantine station, a "hush-hush" commando/intelligence base and a RAAF flying boat base. Its use during the "yellowcake war" is also of historical interest.

Perhaps the most evocative use being its post-war use as a quarantine/holding station for "Boat People"—refugees from Vietnam, Timor and other war-torn Asian countries who sought political asylum in Australia. For these people, with their confiscated boats, in various stages of disrepair drawn up in the mangroves around them, Quarantine Island was Australia. It was sanctuary and it was their new home to be. For Australia it was the beginning of a new era in racial upheaval and an irreversible shift in population make-up.

During this era, Quarantine Island, like other quarantine stations involved with mass immigrations and historic penal settlements such as Port Arthur and Norfolk Island, suffered a general disdain of its inhabitants by the long term Australian populace. Time eventually showed that some of Australia's greatest pioneers and leaders emerged from behind their walls, barriers and social mores. Most of these places have taken on new roles and understandings all over the world and are now being recognised as vital heritage links between races, populations and historic eras.

The "Boat People" phase of Quarantine Island with it’s racial overtones and prejudices must rank in Northern Territory
social history along with the indentured Chinese era in gold mining. To a lesser understood degree the "hush-hush" era had its international ramifications. Foreign nationals were being interrogated and racial prejudices and nationalism exploited to their fullest. Men who would normally have dismissed other races, particularly if they were coloured, as inferior and ignorant - were learning to trust and admire their acumen. Training for operations that in more than 50% of the cases resulted in death was carried out on this island by Timorese, Javanese, Portuguese, Indonesians, Malays, Phillipinos, Dutch, English, Australians and men of other diverse nationalities.

That some survivors and families of the "Boat People" and the "hush-hush" operators will want to pay nostalgic trips back to the island is indisputable fact - what they see is up to our current generation and its perception of heritage.

The recommendations in this report are based on the premise that this island is a vital link in our heritage and that sufficient relics remain to illustrate some of its uses and to act as educational aids in interpretation of its history and reminders to involved families and future visitors that we care and wish to see the proofs of our history passed on to future generations in safety.

The history of the island is slow to emerge, largely because it was out-of-bounds to the general public up until a few years ago. Only recently have the commandos and insurgents been prepared to break their wartime vows of silence to begin talking and writing about the appalling blunders and bravery, ignorance and clever deduction, frustration and success the activities centred on this island produced. Typical of this movement are books\(^3\) and feature films (eg. exploits in the mv. KRAIT to destroy shipping in Singapore Harbour\(^4\) and subsequent attempts to repeat by submarine\(^5\)); which are emerging and are being admired by an incredulous public who had been kept blissfully unaware of such exploits by the application of the "SECRET" stamp, probably in an attempt to keep bureaucratic blunders under wraps.

As more of its war time stories are told and more archival evidence is unearthed the significance of Quarantine Island will be increasingly appreciated for its unique role in Australia's history.
SIGNIFICANCE OF SITES

(a) The narrow strip of land containing the relics (SITES 1-20) of the Lugger Maintenance Section including tracks and bush is considered to have high significance as a heritage place in terms of meeting the following CRITERIA FOR THE REGISTER OF THE NATIONAL ESTATE (see Appendix A):

CRITERION A.4
Importance for association with events, developments or cultural phases which have had a significant role in the human occupation and evolution of the nation, State, region or community.

CRITERION B.2
Importance in demonstrating a distinctive way of life, custom, process, land use, function or design no longer practised, in danger of being lost, or of exceptional interest.

CRITERION C.2
Importance for information contributing to a wider understanding of the history of human occupation in Australia.

CRITERION G.1
Importance as a place highly valued by a community for reasons of religious, spiritual, symbolic, cultural, educational, or social associations.

CRITERION H.1
Importance for close associations with individuals whose activities have been significant within the history of the nation, State or region.

(b) That SITES 22-33 have moderate significance as heritage places under the following CRITERIA FOR THE REGISTER OF THE NATIONAL ESTATE.

CRITERION H.1
Importance for close associations with individuals whose activities have been significant within the history of the nation, State or region.

(c) That SITE 21 has low significance under the CRITERIA FOR THE REGISTER OF THE NATIONAL ESTATE.
REQUIREMENTS FOR PROTECTION AND MANAGEMENT OF SIGNIFICANT HERITAGE SITES

The following measures would be required to protect the heritage values of the LMS area:

(a) setting aside the narrow strip of land (shown in FIG. 1) which contains the relics (SITES 1-20) including tracks and bush. The preserved strip to be of sufficient width to ensure a height of skyline which will obscure the port development from the existing track and to minimise noise transmission into the heritage area.

(b) setting aside a 50m wide strip of East Arm extending from the high water mark adjacent to this strip of land.

(c) SITES 22-33 only allowed destruction following precise recording by measurement and photography by a recognised heritage consultant.

(d) SITE 21 be removed to approved storage for possible future use in interpretive display.

An appropriate management plan for the LMS heritage area would contain the following elements:

ACCESS

access to the place should be from the northern end at low level and restricted to pedestrians except for permissive access for vehicles for disabled persons.

SIGNAGE AND INTERPRETATION

All major interpretation should be confined to a new off-site building adjacent to parking facilities. Relic from SITE 23 to be displayed and interpreted.

Because this place will mean all things to a lot of people, signage should be kept to an absolute minimum within the heritage place proper. It must be considered that nostalgia will play a large part in visitations for many, for say, the next 50 -70 years (Boat People children) and then visitation will revert to mainly history buffs and succeeding families.

A returning "boat" person would be astonished to see the site of the hospital, totally excavated, and replaced with cargo and ship handling facilities. However, being able to wander the pristine mangroves area where they parted from their boats
will be more than simple compensation. They will also have walked amidst the adjacent retained LMS sites and these will bring back memories.

To the commando, the site where his Headquarters and actual hut or the old radio shack may have disappeared but on the old boat handling side there will be a tribute left to his unsung duties and lost comrades. To the lepers who once relied on the boats to bring water and other victuals to Channel Island, the old workshop slab and slipway will still be there.

Returning Catalina crews and family should find ample documented and photographic evidence of the RAAF and US involvement on the island in the interpretation centre as should returning medical staff and quarantine officers.

The militant "yellowcake" unionist and conservationist should also find documentary and photographic evidence of that person's stand for believed principles.

VEGETATION CONTROL

Total vegetation control by herbicides must be maintained for a minimum of two metres on and around all building relics.

FURTHER DOCUMENTATION

Before any disturbance of sites 19-33 takes place each site to be affected must be fully recorded by measured drawings, site location plans and photography.

ISOLATE FROM FUTURE WORKS

During all construction phases of the port facility the heritage place should be clearly fenced with "Dayglo" pvc strip meshing supported on star pickets with adequate signage to exclude any possible intrusion of earth moving equipment.
DESTRUCTION IMPACT

The nominated heritage area in FIG.1, if destroyed, will be an irreversible loss to the Northern Territory, to Australia and to many of our WWII allies.

It is entirely unique to Australia in its WWII and "Boat People" roles, particularly from an international joint usage point of view.

Its importance and uniqueness is still evolving, hence it is difficult to assess in its eventual potential for visitation by Australians and other races who shared in its life but it is certain it will eventually assume a shrine-like atmosphere. The opportunity to preserve this must not be lost.

For a small amount of planning restraint this area can be preserved for the education of future generations.

3 Typical of such books is: MURRAY, W. Hunted, A Coastwatcher's Story, Rigby Ltd.
4 COURTNEY, G.B. Silent Peat. R.L. and G.P. Austin, McCrae, 1983
5 Operation JAYWICK, 1943
6 Operation SAWAU, 1944.
CRITERIA FOR THE REGISTER OF THE NATIONAL ESTATE

Without limiting the generality of sub-section (1) of the Australian Heritage Commission Act, a place that is a component of the natural or cultural environment of Australia is to be taken to be a place included in the national estate if it has significance or other special value for future generations well as for the present community because of:

CRITERION A: ITS IMPORTANCE IN THE COURSE, OR PATTERN, OF AUSTRALIA'S NATURAL OR CULTURAL HISTORY

A.1 Importance in the evolution of Australian flora, fauna, landscapes or climate.
A.2 Importance in maintaining existing processes or natural systems at the regional or national scale.
A.3 Importance in exhibiting unusual richness or diversity of flora, fauna, landscapes or cultural features.
A.4 Importance for association with events, developments or cultural phases which have had a significant role in the human occupation and evolution of the nation, State, region or community.

CRITERION B: ITS POSSESSION OF UNCOMMON, RARE OR ENDANGERED ASPECTS OF AUSTRALIA'S NATURAL OR CULTURAL HISTORY

B.1 Importance for rare, endangered or uncommon flora, fauna, communities, ecosystems, natural landscapes or phenomena, or as a wilderness.
B.2 Importance in demonstrating a distinctive way of life, custom, process, land-use, function or design no longer practised, in danger of being lost, or of exceptional interest.

CRITERION C: ITS POTENTIAL TO YIELD INFORMATION THAT WILL CONTRIBUTE TO A UNDERSTANDING OF AUSTRALIA'S NATURAL OR CULTURAL HISTORY

C.1 Importance for information contributing to a wider understanding of Australian natural history by virtue of its use as a research site, teaching site, type locality, reference or benchmark site.
C.2 Importance for information contributing to a wider understanding of the history of human occupation of Australia.

CRITERION D: ITS IMPORTANCE IN DEMONSTRATING THE PRINCIPAL CHARACTERISTICS OF:
(I) A CLASS OF AUSTRALIA'S NATURAL OR CULTURAL PLACES; OR
(II) A CLASS OF AUSTRALIA'S NATURAL OR CULTURAL ENVIRONMENTS

D.1 Importance in demonstrating the principal characteristics of the range of landscapes, environments or ecosystems, the attributes of which identify them as being characteristic of their class.
CRITERION D:
ITS IMPORTANCE IN DEMONSTRATING THE PRINCIPAL CHARACTERISTICS OF:
(I) A CLASS OF AUSTRALIA'S NATURAL OR CULTURAL PLACES; OR
(II) A CLASS OF AUSTRALIA'S NATURAL OR CULTURAL ENVIRONMENTS

D.2 Importance in demonstrating the principal characteristics of the range of human activities in the Australian environment (including way of life, custom, process, land-use, function, design or technique).

CRITERION E:
ITS IMPORTANCE IN EXHIBITING PARTICULAR AESTHETIC CHARACTERISTICS VALUED BY A COMMUNITY OR CULTURAL GROUP

E.1 Importance for a community for aesthetic characteristics held in high esteem or otherwise valued by the community.

CRITERION F:
ITS IMPORTANCE IN DEMONSTRATING A HIGH DEGREE OF CREATIVE OR TECHNICAL ACHIEVEMENT AT A PARTICULAR PERIOD

F.1 Importance for its technical, creative, design or artistic excellence, innovation or achievement.

CRITERION G:
ITS STRONG OR SPECIAL ASSOCIATIONS WITH A PARTICULAR COMMUNITY OR CULTURAL GROUP FOR SOCIAL, CULTURAL OR SPIRITUAL REASONS

G.1 Importance as a place highly valued by a community for reasons of religious, spiritual, symbolic, cultural, educational, or social associations.

CRITERION H:
ITS SPECIAL ASSOCIATION WITH THE LIFE OR WORKS OF A PERSON, OR GROUP OF PERSONS, OF IMPORTANCE IN AUSTRALIA'S NATURAL OR CULTURAL HISTORY

H.1 Importance for close associations with individuals whose activities have been significant within the history of the nation, State or region.
SITE 5 IN FOREGROUND, SITE 6 BEHIND IS AN EXCELLENT EXAMPLE OF A HORIZONTAL INCINERATING LATRINE.

SITE 10. KITCHEN WITH STOVE SURROUND, SITE 8 (MESS #1) BEHIND.

CONCRETE PATH CONNECTS SITE 17 TO SITE 19.

SITE 16. ENGINE ROOM CONCRETE SLAB AND MACHINERY BASES.

SITE 17. LMS WORKSHOP AT HEAD OF SLIPWAY (SITE 18).
Commandos re-create a wartime raid

By DI WEBSTER, Pulau Bukum, Singapore, Wednesday

Dwarfed by the towering hulks of passing ships, their military fatigues soaked with sweat and sea water, 14 Australian and Singaporean commandos rowed canoes into Singapore's bustling harbor today in a dramatic re-enactment of Operation Jaywick, one of the most audacious allied missions of World War II.

Fifty years ago this month, after a tense voyage through Japanese-patrolled seas, six members of an elite British-Australian military task force slipped silently into the same waters, then enemy occupied, and blew up 39,000 tonnes of Japanese merchant shipping before stealing back to Australia undetected.

In the re-enactment, eight SAS commandoes from Australia and six Singapore Armed Forces personnel are paddling collapsible two-man canoes — the same design used in the original raid — 200 kilometres along the route taken in 1943: from Indonesia's Riau Archipelago to Pulau Bukum, an island near Singapore, and back again.

"I was always impressed by the daring of the original raid," said Sergeant Jim Grierson, a 13-year veteran of the SAS. "Though their predecessors moved under cover of darkness, modern Singapore's clogged waterways were deemed too dangerous for an evening marathon. The commandos, their faces smeared with sun-block, are instead battling equatorial temperatures and dehydration. "We are sweating our body weight every couple of hours," said Major Danny Harley, 32, the coordinator of the exercise.

Ready for action: Sergeant Jim Grierson shares a canoe with a local commando on arriving in Singapore's waters for the re-enactment of Operation Jaywick. "I was always impressed by the daring of the original raid," he says.
Veterans remember 10 beheaded Diggers

By DI WEBSTER,
Singapore, Sunday

A group of Australian World War II veterans paid tribute today to 10 comrades beheaded by Japanese forces in Singapore. The service marked the end of a search for the site where the executions took place, now a footpath beside Singapore Polytechnic sports field.

The men were captured in 1944 during Operation Rimau, an unsuccessful Allied raid on Japanese shipping in Singapore harbor. It followed Operation Jaywick a year earlier, in which seven Japanese ships were blown up by a British and Australian taskforce using canoes and limpet mines.

Today, about 50 people, former members of Z Special Unit and their families, gathered beside the field, which was described by Senior Chaplain Brian Rayner of the Australian Navy as a sacred site. He laid a single poppy on the brick pavement and an army bugler played the 'Last Post'.

Japanese prisoners of war exhumed the remains of the six Australians and four Britons after the war, but there was no record of where the three graves were found.

A Scottish doctor who witnessed the exhumation was able to pinpoint where the men died. Then an officer in the British Army, Dr Roderick Ross, determined that the remains confirmed a Japanese report that the graves contained the Rimau soldiers. He found blindfolds and rope.

"At that time I spent the whole morning memorising the spot, for I well knew that some day, someone would want to know where the atrocity took place," he said.

All 23 servicemen who took part in Operation Rimau died. They were attempting to repeat the raid in which six servicemen paddled canoes into the harbor. Veterans and their families were to hold a vigil on Singapore harbor tonight.

Mr Horrie Young, one of many World War II veterans in Singapore yesterday, reads about Australia's heroes.
The raid was the brainchild of Captain Ivan Lyon, a 28-year-old military intelligence expert with the Gorden Highlanders whose wife and son were imprisoned in Japanese-occupied Singapore.

On 2 September 1943, posing as an Indonesian trading vessel, a former Japanese fishing boat called the Krait and a crew of 14 set out from Exmouth Gulf in Western Australia. On board was a supply of limpet mines and light, collapsible canoes. Captain Lyon, by then a major, was in command of the operation. His first task was to tell the stunned crew where they were headed. As the vessel neared enemy waters, the men hoisted the Japanese flag, changed into Malay-style sarongs and smeared black dye over their bodies.

Sixteen harrowing days after leaving Australia, with the lights of Singapore glowing a mere 25 kilometres away, the Krait deposited the six chosen operatives, their canvas-covered canoes and supplies on Pandjang Island in Indonesia’s Riau Archipelago. The Krait, named after a small but highly venomous Indonesian snake, left to hide out along the south-west coast of Borneo and the crew promised to rendezvous two weeks later.

After two days rest, the operatives began a furtive island-hop, hiding in the mangroves of deserted beaches by day and paddling in the dark of night, finally arriving at tiny Subar Island on 25 September. They were just 13 kilometres from Singapore water.

The next night, blackened from head to toe, the men set off on the final leg of their brazen mission. Limpet mines were tucked into their cramped two-man canoes and, in case the worst happened, each commando carried a cyanide capsule.

Singapore was brightly lit and as their oars cut quietly through the calm sea, the nervous operatives could see Japanese sentries patrolling the wharf. As they approached the western anchorage between Pulau Bukum and Singapore’s southern coast, the party split into three sections.

Timing themselves by the chime of a clock on Victoria Hall, the men drew alongside a total of seven ships, quietly attaching limpet mines under the vessels’ waterlines.

The mines had all been equipped with six-hour fuses. By the time the first blast erupted just before dawn, all six men had scrambled ashore at Indonesia’s Batam and Dongas Islands.

Militarily, Jaywick was a masterstroke. For many internees and civilians in Singapore, however, the mission signalled the end of the terror campaign by the Japanese military police.

A year after Operation Jaywick, Captain Lyon led a similar mission, codenamed Operation Rimau, back to Singapore. It ended in the deaths of all 23 operatives.

About 100 Z Special Unit veterans and their families will hold an evening vigil off Pulau Bukum on 26 September. Among them will be four Jaywick operatives, including Able Seaman Arthur Jones, the only survivor of the six who paddled into Singapore 50 years ago. The others died in Operation Rimau.